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A REPORT

TO THE

Director of Public Improvements

OF THE

City of Columbus, Ohio,

ON

THE PROPER DISPOSAL OF THE SEWAGE OF THE CITY, TOGETHER WITH PLANS AND ESTIMATES OF COST.

ALSO UPON

A PROJECT FOR THE SEWERAGE AND DRAINAGE OF THAT PORTION OF THE CITY LYING WEST OF THE SCIOTO RIVER, ACCOMPANIED BY DETAILED PLANS AND ESTIMATES.

MAY 1st, 1898.

JULIAN GRIGGS, C. E.,
Chief Engineer Dep't Public Improvements, City of Columbus.

JOHN W. ALVORD, Member Am. Soc. C. E.,
Consulting Engineer, Chicago.

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348 N. HIGH STREET. COLUMBUS, OHIO.

ILLUSTRATIONS BY
TERRY ENGRAVING COMPANY,
COLUMBUS, OHIO.

Discussion of the Proper Method for the Purification of the Sewage of the City.

MAY 1st, 1898.

TO THE HON. FELIX A. JACOBS, ESQ.,
Director of Public Improvements,
City of Columbus, Ohio.

DEAR SIR:—In accordance with the instructions received from you on January 19th, 1898, we have conducted an investigation into the question of the disposal of the sewage of the City of Columbus, and the problem of the proper sewerage and drainage of that portion of the city lying west of the Scioto river.

The wide scope of the subject of the proper disposal of the sewage of the city, together with the complicated nature of the problems of the sewerage and drainage of the West Side, has required extensive surveys, continuous gaugins gof the river, measurements of the flow of the intercepting sewer, and an investigation of certain methods in other cities. This work has of necessity consumed a period of several months.

Detailed plans of the sewer system upon the West Side are now practically completed. They include about sixty sheets of drawings and profiles. Seven different methods of disposing of the sewage have been studied, embodied upon general plans and estimated. In recommending a project from among those considered in detail, we have carefully compared their relative advantages, and endeavored to be guided by the city's best interests in this important matter.

These recommendations with our reasons therefor, are more fully set forth in the accompanying report, which for convenience we summarize as follows:

GENERAL CONCLUSIONS.

1st. We conclude that the sanitary sewers already constructed upon the West Side are not well adapted for the use for which they were intended.

2nd. We find that this system may be advantageously altered with but slight additional expense so as to provide for storm-water drainage to the extent of its capacity.

3rd. In view of the pressing nature of the sewage disposal problems upon the city as a whole, and the great cost of any method of relief, due largely to the use of the combined system of sewers. We recommend the adoption of the separate system for the West Side with an outlet at the intersection of the river and the Stimmel road.

4th. We find that the entire sewage of the city, if purified, must be pumped to the purification works. We also find that the sewage from the West Side must in addition be pumped into the river during certain stages of high water. We further find that efficient storm water drainage for the West Side will require that the rainfall on this district be also pumped into the river at certain stages of high water. We therefore suggest that these different operations be combined in one pumping station and recommend that it be located on the east bank of the Scioto river near the intersection of the Stimmel road.

We would especially point out that when engaged in pumping the storm water and sewage from the West Side in times of high water, it will not be necessary to pump the sewage of the East Side for purposes of purification, and vice versa, consequently this pumping station will be capable of performing a double duty. We therefore advise that the capacity of the machinery in the station be sufficient to raise 40,000,000 gallons each twenty-four hours twenty-five feet in height, and be so connected as to perform all the work above mentioned.

5th. We recommend that there be constructed a low levee north of and parallel with Greenlawn Avenue, between the river levee and the higher lands to the west, of just sufficient height to prevent back-water from the south from encroaching upon the populated area.

6th. We recommend that the dry weather flow of the northeast sewer now draining into Alum creek, be intercepted near its outlet and be lifted by an automatic electric power station through a cast-iron force main to the summit of the ridge, thence to flow by gravity through the ordinary street sewers to the main intercepting sewer.

7th. We recommend that in extending the sewer system

of Columbus into outlying or suburban districts, the separate system of sewerage be adopted wherever it is practicable.

8th. For the purification of the entire sewage of the city, estimated at the present time at 20,000,000 gallons per day, we advise the use of artificial biological coke breeze filters, covering thirty-six acres of ground and located adjacent to the site, recommended for the pumping station, described in detail as "Project No. 7."

We advise that the sewage first pass through fine screens, the refuse from which should be immediately burned, and thence be lifted by the pumping engines to the first series of coarse grain filters, consisting of eighteen beds of one acre each. After receiving a preliminary purification of several hours in those beds, the effluent should flow to a lower set of beds similar in number and area but finer in grain, where it will receive the remainder of the purification and finally pass into the river.

We suggest that the most satisfactory way to install this system of purification will be to commence with the construction of two acres of coke breeze biological filters which should be operated one full season under the direction of a competent chemist, and that with the confidence thus gained, additions be made to the plant until it is fully able to purify the sewage of the West Side.

ESTIMATES.

We would summarize our estimates of cost in this place for your convenience, as follows:

ENTIRE COST OF RECOMMENDATIONS.

Sewage disposal plant	$508,600.00
Pumping station and connections	69,608.00
Levee north of Greenlawn Avenue	6,200.00
West Side storm water drainage	33,715.00
Main sanitary sewers, West Side	121,729.00
Branch " " "	165,011.00
Alum Creek pumping plant	21,765.00
Total	$926,628.00

It is not intended that this expenditure be regarded as at once necessary. We suggest that a proper commencement upon this important work, which would yield the largest

measure of relief for the smallest reasonable investment, would require the following outlay:

PRESENT OUTLAY RECOMMENDED.

Pumping station and connections	$69,600.00
Storm water sewer in Stimmel Road	25,200.00
Outlets and interceptors	3,720.00
Levee north of Greenlawn Avenue	6,200.00
Main sanitary sewers, West Side	72,763.00
Two acres of filtration beds	18,200.00
Total	$195,683.00

This amount of expenditure will insure relief to the West Side against flood water and will allow cellars to be constructed throughout the district, reducing the difficulties from sub-soil drainage to a minimum. It will furnish sanitary sewerage mains for immediate use in over five miles of streets, and enable adjacent districts to obtain an outlet for such short branch sanitary sewers as may be desired.

It will also install preliminary filters for the disposal works, capable of purifying about 1,000,000 gallons of sewage per day, in accordance with our recommendations.

In considering these important measures, our report naturally divides itself into parts as follows:

PART I. The Final Disposal of the Sewage of the city.
PART II. The Storm Water Problem on the West Side.
PART III. The Sanitary Sewerage of the West Side.
PART IV. The Disposal of the Alum Creek Sewage.

In closing, we respectfully refer you to the body of the report for detailed discussion of these questions, and express our obligation for your kind co-operation in our investigations. We would also take occasion to thank the members of the City Engineering Department and other city officials for their efficient assistance.

All of which is respectfully submitted.

JULIAN GRIGGS,
Chief Engineer, Dept. of Public Improvements.
JOHN W. ALVORD,
Consulting Engineer.

PART I.

The Final Disposal of the Sewage of the City.

LOCATION AND DRAINAGE.

The city of Columbus lies for the most part upon the east bank of the Scioto river, upon high ground. The general form of the city rather resembles a Greek cross. It is located upon three water sheds, two emptying into the Scioto and Olentangy rivers, and one into Alum creek. The sewerage and drainage of that portion of the city lying west of the Scioto river, we discuss at length elsewhere in this report.

The sewage of the eastern watershed of the Olentangy and Scioto rivers is now collected by means of an intercepting sewer, nearly seven miles in length, and discharged a little north of the southern limits of the city. This sewer ranges in diameter from 2½ to 6 feet, and ordinarily flows about one-third full.

The sewage from the eastern portion of the city is emptied directly into Alum creek by a sewer nine feet in diameter. The dry weather flow of this sewer is not large in amount, but the natural waters of the creek are hardly sufficient to accomplish its purification, especially during the dry season of the year.

The Scioto river drains an area above Columbus of 1053 square miles. The Olentangy river with which it here unites, has a drainage area of 612 square miles. The united streams are sufficient for the purification of the sewage of Columbus a large portion of the year, but like all western rivers, they are extremely variable, and their united flow falls to a very small relative quantity in the late summer and early autumn months. The flood flow of the Scioto river below Columbus, easily and often reaches 30,000 to 40,000 cubic feet per second, rising from 15 to 18 feet above low water. The flood of March 23, 1898, which was the greatest and most disastrous on record, is believed to have passed fully 75,000 cubic feet per second at its maximum stage. Its maximum rise was 18¾ feet

at the Columbus State Hospital pumping station, or 2¾ feet higher than ever before reached at that point. The average flow for six months of the wet season is about 600 cubic feet per second, during which time it seldom falls as low as 250 cubic feet per second. In dry weather of summer and autumn, on the other hand, the flow is very small. During 1897, for August, September and October, its average was about 30 cubic feet per second, and consisted of but little more than the sewage of the city, slightly diluted. At this stage, as would be expected, the river is extremely foul, and becomes a menace to the health and comfort of the people of the lower part of the city and the residents of the valley below.

The following interesting table gives the pollution of the Scioto river from Kenton to Circleville, together with the drainage area and population. Particular attention is called to the column denoting the proportion of sewage in the river as shown by chlorine. It will be observed that in October, usually the dryest month of the season, 98 per cent. of the flow at the Frank road, just below Columbus, has, at some time, been polluted :

TABLE SHOWING PER CENT. OF SEWAGE WATER IN SCIOTO RIVER, AS INDICATED BY CHLORINE.

ALSO GIVING APPROXIMATE DRAINAGE AREA AND POPULATION ABOVE SAMPLING POINTS, BY PROF. N. W. LORD, CHEMIST OF THE OHIO STATE UNIVERSITY — MADE FOR THE OHIO STATE BOARD OF HEALTH.

Approximate distance in miles.	Station.	Per ct. of sewerage average June to Dec.	Per ct. of sewerage in October.	Area drained.	Total population.
0	Kenton	.....	4	153	6,685
2	Kenton, below	14	39	153	14,525
	Marion, above	.....	.....	109	4,905
	Marion, below	.....	.....	109	22,688
49	Girls Industrial Home	.....	18	962	68,921
50	Girls Industrial Home, below	.....	22	.....	.....
58	Wyandotte grove	7	13	1,023	71,621
61	Jones' dam	6	12	1,038	72,221
66	Columbus, Sandusky st. bridge	12	18	1,053	72,921
70	Columbus, Frank road bridge	51	98	1,565	263,419
77	Shadeville	42	75	1,650	273,200
....	Circleville, above creek	.....	.....	2,625	3.1,000
91	Circleville	10	22	3,160	342,000

CHEMICAL ANALYSIS OF THE SCIOTO RIVER FROM KENTON TO COLUMBUS, OHIO,

For Six Months, June to December, 1897,

By Prof. N. W. Lord, Chemist for the Ohio State University, Made for the Ohio State Board of Health.

Approximate distances—miles.	Locality of Sample.	Date of Sample. Month.	Day.	Color.	Turbidity.	Sediment.	Odor.	Oxygen Required.	Ammonia. Free.	Ammonia. Albuminoid.	Nitrogen. Nitrates.	Nitrogen. Nitrites.	Chlorine.	Hardness. Temporary	Hardness. Permanent	Total Solids.	Volume Solids.
....	Kenton — above town	June.	12	0.4	Very slight.	Marked	None	1.14	.0062	.0574	.150	.0024	0.20	21.0	22.6	73.0	10.0
	" " "	July.	16	0.4	Distinct	"	Earthy	1.02	.0098	.0462	.042	.0003	0.10	23.2	..x..	80.5	11.0
	" " "	Aug.	25	0.2	Marked	Distinct	None	0.61	.0084	.0292	.....	.....	0.25	23.4	13.0	62.5	7.5
	" " "	Sept.	25	0.4	Distinct	Slight	Slight earthy	0.62	.0028	.0288	.....	.....	0.38	22.6	12.2	67.0	9.0
	" " "	Oct.	23	0.3	"	"	Sour, musty	0.54	.0030	.0240	.....	.....	0.33	25.2	11.2	60.5	9.3
	" " "	Dec.	1	0.5	Marked	"	Musty	1.14	.0571	.0638	.938	.0030	0.15	10.4	51.0	107.5	19.5
2	Kenton — below town	June.	12	0.45	Very slight.	Slight	Slight	1.06	.0142	.0430	.160	.0026	0.40	21.4	22.8	71.0	10.0
	" " "	July.	16	0.3	Distinct	Marked	Offensive	1.53	.0476	.1720	.....	.....	0.45	3.2	..x..	72.0	12.5
	" " "	Aug.	25	0.2	"	"	"	0.87	.0384	.1328	.....	.0010	0.65	23.2	11.8	60.5	9.5
	" " "	Sept.	25	0.35	Slight	Distinct	Oily	0.70	.0764	.0360	.....	.0003	1.25	23.8	11.4	64.5	11.0
	" " "	Oct.	23	0.3	Clear	Marked	Slight offensive	0.75	.2160	.0588	.....	.0005	1.80	25.8	11.4	65.0	12.0
	" " "	Dec.	1	0.5	Distinct	Slight	Marked musty	1.13	.0584	.0624	.944	.0030	0.20	11.8	46.6	97.5	16.0
49	Girls' Industrial Home — above	Oct.	7	0.15	Clear	Slight	Very faint musty	0.50	.0078	.0308	....	Ftrace	0.87	17.0	11.2	48.5	10.0
	" " " "	Oct.	26	0.25	Slight	"	Slight musty	0.46	.0054	.0276	.....	.....	0.95	21.0	10.8	53.0	10.5
	" " " "	Dec.	2	0.50	Marked	"	Earthy	0.83	.0128	.0418	.530	.0025	0.20	14.4	14.8	51.2	11.5
	" " " "	Dec.	2	0.50	"	"	"	0 85	.0124	.0416	.640	.0025	0.15	13.8	14.8	49.2	11.0
50	Girls' Industrial Home — below	Oct.	7	0.15	Clear	Slight	Faint musty	0.51	.0114	.0274	Trace.	.0003	1.03	17.0	12.2	50.0	10.0
	" " " "	Oct.	26	0.25	"	Very slight.	Slight musty.	0.48	.0070	.0272	. .	Trace.	1.00	21.0	11.0	52.5	9.0
	" " " "	Oct.	26	0.20	"	" "	Slight musty, sour.	0.47	.0068	.0278	.....	.0002	1.10	21.0	11.3	52.5	10 0
	" " " "	Dec.	2	0.40	Marked	Slight	Slight musty	0.83	.0126	.0412	.598	.0025	0.17	14.0	14.2	50.1	11.0
58	Wyandotte Grove	June.	14	0.2	Slight	Marked	Trace sweet	0 54	.0040	.0260	.029	.0002	0.40	19.4	5.2	44.5	9.0
	" "	July.	17	0.3	Marked	"	Very faint	0.55	.0028	.0378	.017	.0002	0.55	18.2	9 4	50.0	7.5
	" "	Aug.	23	0.2	Slight	Slight	None	0.59	.0096	.0344	.003	.0003	0.38	17.2	8.8	44.0	8.0
	" "	Sept.	23	0.15	Very slight.	Distinct	Slight earthy	0.51	.0098	.0316	.003	.0002	0.78	17.6	12.6	55.0	9.0
	" "	Oct.	21	0 2	Distinct	Slight	Earthy	0 45	.0048	.0268	.005	.0002	0.77	20.0	14.0	58 5	9.0
	" "	Dec.	3	0.5	Marked	Distinct	Slight earthy.	0.81	.0100	.0366	.630	.0020	0.15	14 6	13.2	46.7	10.0
61	Jones' Dam	June.	14	0.2	Slight	Marked	None	0.58	.0037	.0276	.034	.0002	0.45	19.4	4.8	45.5	10.0
	" "	July.	17	0.3	Marked	"	Trace	0.59	.0028	.0398	.020	.0003	0 38	18.4	10.4	51.0	9.0
	" "	Aug.	23	0 2	Slight	Distinct	Slightly sour	0.65	.0092	.0380	.008	.0003	0.41	17.8	8.0	45.0	7.5
	" "	Sept.	23	0.2	Very Slight.	Slight	Slightly earthy	0.50	.0088	.0306	.....	.0003	0.73	17.6	11.6	51.0	9.5
	" "	Oct.	21	0.2	Distinct.	"	Earthy	0.46	.0082	.0296	.005	.0006	0.73	19.2	12.4	54.5	9.0
	" "	Dec.	3	0.5	Marked	Distinct	Slightly earthy	0 84	.0102	.0354	.650	.0025	0.17	14.0	13.6	46.4	10 0
66	Columbus — Sandusky St. bridge	June.	14	0.2	Distinct.	Distinct	None	0.52	.0110	.0342	.032	.0007	0.70	19.0	6.2	48.0	10.0
	" " "	July.	17	0.3	Marked	Marked	Faint musty	0.62	.0048	.0376	.026	.0002	0.40	18.4	9 2	48.0	9.5
	" " "	Aug.	23	0.2	Very Slight.	Slight	Sour "	0.61	.0200	.0394	.007	.0015	1.01	18.0	7.8	44.5	8.5
	" " "	Sept.	23	0.2	" "	Distinct	Slight "	0.58	.0280	.0420	.....	.0005	1.15	15.2	10.6	46.0	10.0
	" " "	Oct.	21	0.15	" "	Slight	" offensive	0.58	.0086	.0392	.004	.0004	0.87	15.8	9.8	52.5	10.0
	" " "	Dec.	3	0.6	Marked	Distinct	" earthy	0.91	.0110	.0418	.582	.0025	0.23	14.4	13.6	47.4	10.5
70	Columbus — Frank Road bridge.	June.	12	0.2	Slight	Slight	Offensive	1.17	.2322	.1130	.003	Trace.	1.60	23.8	8.6	49.5	8.0
	" " "	July.	17	0.4	Distinct	Very marked.	Offensive, oily	1.11	.1644	.0896	.....	.0188	1.30	18.2	8.4	44.0	8.5
	" " "	Aug.	23	0.4	Very slight.	Distinct	Offensive	1.26	.3824	.1136	.....	.....	2.11	25.6	9.4	52.0	13.5
	" " "	Sept.	23	0.3	Distinct	Marked	Offensive, musty	1.36	.7600	.0876	.....	Trace.	3.90	33.0	11.2	68.0	11.0
	" " "	Oct.	21	0.5	Very marked.	"	Very offensive	2.39	1.0170	.2340	.....	.....	4.15	34.6	9 2	76.5	14.0
	" " "	Dec.	4	0.4	Marked	"	Oily	1.05	.0880	.0780	.442	.0070	0.60	16.0	13.4	47.2	9.0
77	Shadeville bridge	July.	17	0.25	Very slight.	Marked	Slight earthy	0.61	.1352	.0360	.020	.0395	1.45	22.6	6.6	47.0	8.0
	" "	Aug.	23	0.3	" "	Slight.	" sour	0.85	.0176	.0756	.049	.0150	1.68	24.2	7.0	47.5	9.0
	" "	Sept.	23	0.3	Clear	Marked	" offensive	0.91	.6630	.0760	....	.0022	2.85	31 4	6.8	56.0	9.5
	" "	Oct.	22	0.5	Marked	Distinct	Offensive	1.49	.7960	.1620	.....	.0002	3.15	35.6	5.2	60.5	8.5
	" "	Dec.	4	0.4	"	"	Musty	0.91	.0508	.0536	.536	.0037	0.53	15.2	11.6	43.8	7.6
91	Circleville — above Darby creek	June.	14	0.15	Clear	Decided	None	0 59	.0112	.0326	.043	.0026	0.65	24.4	0.8	39.5	7.0

This is also well illustrated by the accompanying tables, showing the results of the chemical survey of the river, made by Prof. Lord, under the direction of the State Board of Health, during the year 1897.

The present sewer system of Columbus was commenced about the year 1850, and like most sewerage work of that period and earlier, was brought into existence by the necessities of the hour.

No general design was ever studied or adopted, and definite information relative to the system is not extensive, except such as is afforded from time to time by personal investigation or recent surveys.

The size of the sewers do not exhibit that symmetry through the city which would have resulted from comprehensive plans, and probably but a small proportion of the sewers have been built by the application of the correct principles of design. Where sewers thus built have been found too small, they have been rebuilt, or relief sewers constructed. Where sewers have been made too large, the public directly interested have been gratified because they were not too small.

All sewers have been constructed on the combine system, the house wastes and storm water being provided for in the same drain.

A recent search among the records of the city hall show that there is now in existence 143.6 miles of public sewer, constructed at a total cost, exclusive of catch-basins, of about $2,410,000.00. Besides this amount, there is considerable mileage in the public streets, of sewer construction by private interests, of which there is but scanty record.

THE PURIFICATION OF SEWAGE.

Sewage may be defined as water contaminated with the wastes of life. These wastes are composed of complex and unstable chemical compounds, which are resolved by the process of nature into more simple and harmless forms, mineral and gaseous. The operation as now understood, is accomplished by innumerable swarms of bacteria, operating generally in the presence of a sufficient supply of oxygen, and is everywhere taking place under our eyes in nature. The operation becomes obnoxious and dangerous to us only when unduly concentrated, as is the case in malarious swamps, de-

composing bodies of animals, or the results of thickly inhabited population centers. Under such circumstances the want of oxygen in sufficient quantities, and other proper and suitable conditions for the growth of certain necessary forms of bacteria, not only allows offensive and unhealthful gases to be created, but dangerous forms of bacteria are propagated, which, if allowed to seize upon living tissue, become fatal to human life.

There is theoretically but one system of purifying the sewage which a large community will create, and that is to so arrange the disposition of these waters that the process which nature intends for this purpose, and provides, when permitted, with boundless prodigality, shall have the fullest possible scope of action, unhampered and unhindered.

To this end all sanitary science is directed, and along these lines all sanitary success has been won.

The various methods by which nature is thus allowed, and in some cases assisted to do her work, are very large in number, and shade into each other in great variety. Their differences as to principle, when properly conceived, are generally slight, while in detail they may vary greatly. There is no general form which can be said to be the "best method" of purifying sewage, but each locality presents its local problems, which can not be met by a "sovereign specific."

The best known names in the field of sewage disposal methods are "Broad Irrigation," "Intermittent Filtration," "Chemical Precipitation," and "Dilution," but the distinction between them in principle is not so great as the mere names would indicate.

Broad Irrigation may be defined as the discharge of the sewage upon land, in such quantities and with a certain intermittency so that the oxygen in the air and the bacteria of the soil and sewage, may produce the chemical reactions before mentioned, and known as nitrification. Plant life and growth is generally understood to be an essential feature of Broad Irrigation or sewage farming, and to a certain extent plant life thrives upon the constituents of the dissolving organic matter.

Intermittent Filtration upon land differs but little from broad irrigation, but is usually understood to involve a greater

rate of flow with a more porous material in the absence of plant life. Although this latter requisite does not always distinguish it, both methods depend upon bacterial action and oxidation. Intermittent filtration is not however necessarily confined to soil ; gravel, ballast, broken stone and coke screening have been found very efficient when properly used.

Chemical Precipitation consists in separating the suspended matters in the sewage and treating them separately from the dissolved impurities. This is done by chemical coagulents, and when separated, the impurities have to be treated by one or the other methods here defined, before purification can be said to be complete.

Dilution consists in bringing the sewage into contact with a sufficient quantity of fresh water, so that the dissolved oxygen which such water always contains can promote the bacterial action and subsequent nitrification. Dilution is the most common and inexpensive form of purification where conditions render it practicable, and is so commonly used as not to be considered by the unthinking as a scientific form of purification at all. Nevertheless the principles under which it operates are quite the same as land methods, and their limitations are well understood.

In making an application of these methods to the local conditions of the city of Columbus, it will be observed that in nearly every case combinations are preferred, rather than the simple forms above defined ; but this is only another illustration of the indefiniteness of any single name to convey an idea of the principles to be applied. Those principles may be briefly stated as follows :

The sewage in its fresh state before decomposition has set in must be brought into contact with wide diffusion at innumerable points, with certain forms of nitrifying bacteria in the presence of a sufficient supply of oxygen, and retained under the conditions a proper length of time for complete chemical change to be accomplished. This properly done, the sewage is found to be purified without offense or odor, and without danger to human health in any way.

THE EXPERIENCE OF OTHER CITIES.

Before proceeding to consider in detail the methods which may be applied for the purification of the sewage of Colum-

bus, it may be interesting and instructive to observe how this important question has been dealt with in other cities of equal or greater size. Accordingly, the following table has been compiled, giving a list of such cities, their population, quantity of sewage flow, briefly describing the methods adopted for the purification of the same, and covering as far as possible all the cities of 100,000 population or over :

Place, Population, and Daily Sewage Flow, in gallons.	METHOD OF DISPOSAL.
London, England. Population, 5,000,000. 180,000,000 gallons.	**Chemical Precipitation** by the lime process. The sludge is carried out to the sea in ships, while the effluent from the precipitation tanks is discharged into the River Thames below London, at high tide.
Paris, France. Population, 2,500,000. 117,500,000 gallons.	**Filtration upon land.** Sewage from about one-fifth of the city is carried to a large farm in the valley of the Seine. Preparations are now being made to extend this area by a very large additional amount of land.
Berlin, Germany. Population, 2,000,000. 46,000,000 gallons.	**Broad irrigation** and **intermittent filtration.** Sewage is pumped to three farms with an aggregate area of about 22,000 acres. The city operates the farms with success, and it is said they pay about 2 per cent. upon the investment of $6,000,000, not however including the cost of pumping.
Chicago, Illinois. Population, 1,800,000. Daily flow about 300,000,000 gallons.	**Dilution.** Project now under construction consisting of a drainage canal 28 miles long, costing $35,000,000 and upwards. Intercepting sewers and pumps, $5,000,000 more. Dilution to be on basis of 4 cubic feet per second for each 1,000 population.
Boston, Mass. Population, 600,000.	**Dilution.** The city has about completed at great expense, an elaborate system of intercepting sewers and pumping stations which raise the sewage and convey it to reservoirs on islands on the outer bay, where it is discharged at high tide into the sea.
Glasgow, Scotland. Population, 658,000. About 25,000,000 gal.	**Chemical precipitation.** Sulphate of alumina and lime are used, and the sewage of about one-half of the city is treated. The effluent is filtered through coke filters and afterwards through sand filters. The works were put into operation in 1894, and cost about $335,000.00.
Leeds, England. Population, 367,000. Daily flow, 10,000,000 gallons.	**Chemical precipitation.** Lime process with coke breeze filtration for the effluent. Sludge is given away for fertilizer.
Breslau, Germany. Population, 335,000. 8,500,000 gallons.	**Broad** and **intermittent filtration** upon land.

Birmingham, England. Population, 500,000. 30,000,000 gallons.	**Chemical precipitation,** using lime process. There are large amounts of manufacturing wastes; the sludge is deposited upon land, and the effluent from tanks is irrigated on about 1,200 acres of land farmed by the city.
Manchester, England. Population, 600,000. 18,000,000 gallons.	**Chemical precipitation.** Lime and proto-sulphate of iron are used. The effluent is emptied into the Manchester ship canal, but under protest. Biological coke filters are proposed.
Sheffield, England. Population, 324,000. 10,000,000 gallons.	**Chemical precipitation.** Lime process with coke breeze filtration similar to Leeds and Bradford. Cost about $325,000.
Edinburgh, Scotland. Population, 246,000.	**Broad irrigation.** Portions of the sewage of the city have been irrigated upon Craigentienny meadows for upwards of 200 years.
Bradford, England. Population, 216,000. 8,400,000 gallons.	**Chemical precipitation.** Lime process is used with intermittent flow, the effluent from precipitation is filtered through coke breeze, the coke of which is removed four times a year and used for fuel after drying. The sludge is dried in reservoirs and hauled away free of cost to the city for fertilizer.
Frankfort, Germany. Population, 179,000.	**Chemical precipitation.**
Salford, England. Population, 180,000. 12,000,000 gallons.	**Chemical precipitation.** Lime process, cost about $500,000. The sludge was buried at first, but filter-pressed later. The effluent is emptied into the river Irwell, but experimental filters have been constructed, and further purification is intended.
Providence, R. I. Population, 150,000. 1,500,000 gallons.	**Chemical precipitation.** Project now under construction. Effluent from precipitation tanks to be emptied into Providence bay at high tide, at a point several miles below the city. Sludge will be filter-pressed.
Dantsic, Germany. Population, 109,000. 2,500,000 gallons.	**Broad irrigation** and **intermittent filtration** upon about 700 acres of land, which cost nothing, being a plain of waste sand thrown up by the sea. $57,000 was spent in preparing it for use, and good crops are grown upon it.
Huddersfield, England. Population, 100,000. 15,000,000 gallons.	**Chemical precipitation.** Ferozone Polarite process by International Sewage and Water Purification Co., of London. The effluents are filtered and the sludge is pressed into cakes and given away for fertilizer.
Dortmund, Germany. Population, 100.000.	**Broad irrigation** has succeeded chemical precipitation. Lime and sulphate of alumina were used. The precipitating tanks were vertical with upward flow; the sludge was sold to farmers at a nominal price. No particulars of the land method adopted have come to hand at this writing.

Croyden, England. Population, 100,000. 4,000,000 gallons.	**Broad irrigation** and **intermittent filtration.** Farm consisting of 525 acres, has been in operation since 1860, and has cost about $90,000. The operation of the farm has been very successful.
Worcester, Mass. Population, 100,000. 17,000,000 gallons.	**Chemical precipitation** has been in use about nine years with lime. The sludge has been dried upon about 20 acres of land. The effluent from the precipitation tanks has been emptied directly into Blackstone river, but its condition became so foul with the growth of the city that a large area of intermittent filtration beds are in course of construction for further purifying the effluent. Presses are being installed for the sludge.

No attempt has been made to include cities of less than 100,000 population, but a fair idea of their number may be gathered from the fact that about one-half of the total sewage flow in England alone is now purified in some way before being emptied into the streams, while the number of small cities in that country that are adopting purification, is growing so rapidly that it is difficult to keep track of the newer projects.

It will be noticed that no attempt has been made to include all the cities using the dilution method of disposal. They are very largely in the majority. The two examples cited are interesting cases, where large expense has been incurred to perfect dilution methods. Of the examples cited, then, the following may be taken as a rough generalization :

13	cities	with a population of	8,374,000	use chemical precipitation.
6	"	"	5,390,000	" land methods,
2	"	"	2,400,000	" dilution methods.
			16,164,000,	total.

QUANTITY OF SEWAGE TO BE PURIFIED.

The most essential data for a careful study of different methods of treating the sewage of Columbus, are accurate knowledge of its quantity and quality. With a combined system of sewers the quantity of the sewage is both variable and proportionally large to the population. During the wet season of winter and spring the storm waters find their way into the sewers, not alone directly from the pavement and roofs, but indirectly by percolating through the porous soil. This action extends over periods of many days after the storms have ceased. In the dry weather of summer and fall,

the flow in the sewers from this source is reduced to a minimum.

The period during which this investigation has been in progress having covered some of the months of excessive moisture, it has been comparatively easy to determine with some accuracy the maximum flow of sewage. Selecting a week when the stage of the river still rendered disposal by dilution practicable, but which might be called a comparatively dry week in the wet season, the following gaugings of the main intercepting sewer near its outlet were made with a carefully rated current meter:

GAUGINGS OF THE INTERCEPTING SEWER.

DATE.	TIME.	RATE OF FLOW, GAL. IN 24 HOURS.
Feb. 26th	Forenoon	13,790,000
" 28th	"	15,989,000
March 1st	"	16,669,000
" 2nd	"	14,735,000
" 5th	"	13,171,000
Average		14,780,000

No rain fell during this time or for five days previous to the first gauging, but the season was such that the ground was full of percolating water, and the result gives a fair idea of the amount which may be expected at this time of the year without including actual storm water directly admitted to the sewers. The intercepting sewer drains fully three-quarters of the entire city, including the main business and manufacturing sections, where water is used in the greatest quantity.

Another factor in the quantity of sewage, is the use of water by the population of the city. A study of the present population is shown in the annexed diagram of growth, compiled from reliable sources. (See Plate opposite page 16.)

Upon these data we assume a population at the present time (May 1, 1898) of 115,000 persons, with the possibility that this population may double itself in the next thirty years, and at least reach 160,000 persons before 1925.

A distribution of the population upon the different water sheds, based upon the registered vote of 1896 and 1897, has been made. The water supply for 1897 has likewise been distributed, and an estimate made upon the maximum sewage flow, with the following results:

TABLE SHOWING ESTIMATED DISTRIBUTION OF POPULATION.

WATER SUPPPY AND MAXIMUM FLOW OF SEWAGE ON THE DIFFERENT WATER SHEDS.

Water shed.	How drained.	Estimated population.	Daily water supply—gallons.	Estim't of maxim'm daily sewage flow—gallons.
East Side.....	Drained into intercepting sewer.....	82.000	10,955,000	14,870,000
West Side.....	Not now sewered..	16,000	1,260 000	2,400,000
Alum Creek...	Partially " ...	17,000	1,280,000	2,550,000
Totals	.....	115,000	13,495,000	19,820,000
Gallons per capita			117.35	172.34

In distributing the water supply among drainage areas, we have not taken the average supply per capita for the whole city of 117.3 gallons, but have assumed a consumption of 134 gallons per capita in the east side district, as against 80 gallons in the west side and Alum creek water sheds, which are more largely residential in character. Attention should be called to the fact that the observed dry weather flow of the nine foot circular sewer draining into Alum creek, is about one-half the quantity estimated upon as maximum in this manner, and further, that it is improbable that the entire sewerage system as recommended in this report, will be completed upon the west side for some years to come.

We feel, therefore, that 20,000,000 gallons in each 24 hours, is a safe amount to consider as the maximum quantity of sewage of the city of Columbus, which must be purified at the present time. If the conclusions of this report are correct, for a certain portion of the year the sewage of the city may be disposed of by dilution into the Scioto river directly, and this too at that season when the maximum flow of sewage would occur. Fortunately it is at such seasons of the year that the flow of the Scioto river is abundantly able to purify the sewage of the city. The maximum flow of sewage, then, is not of such importance to us, as are data upon the dry

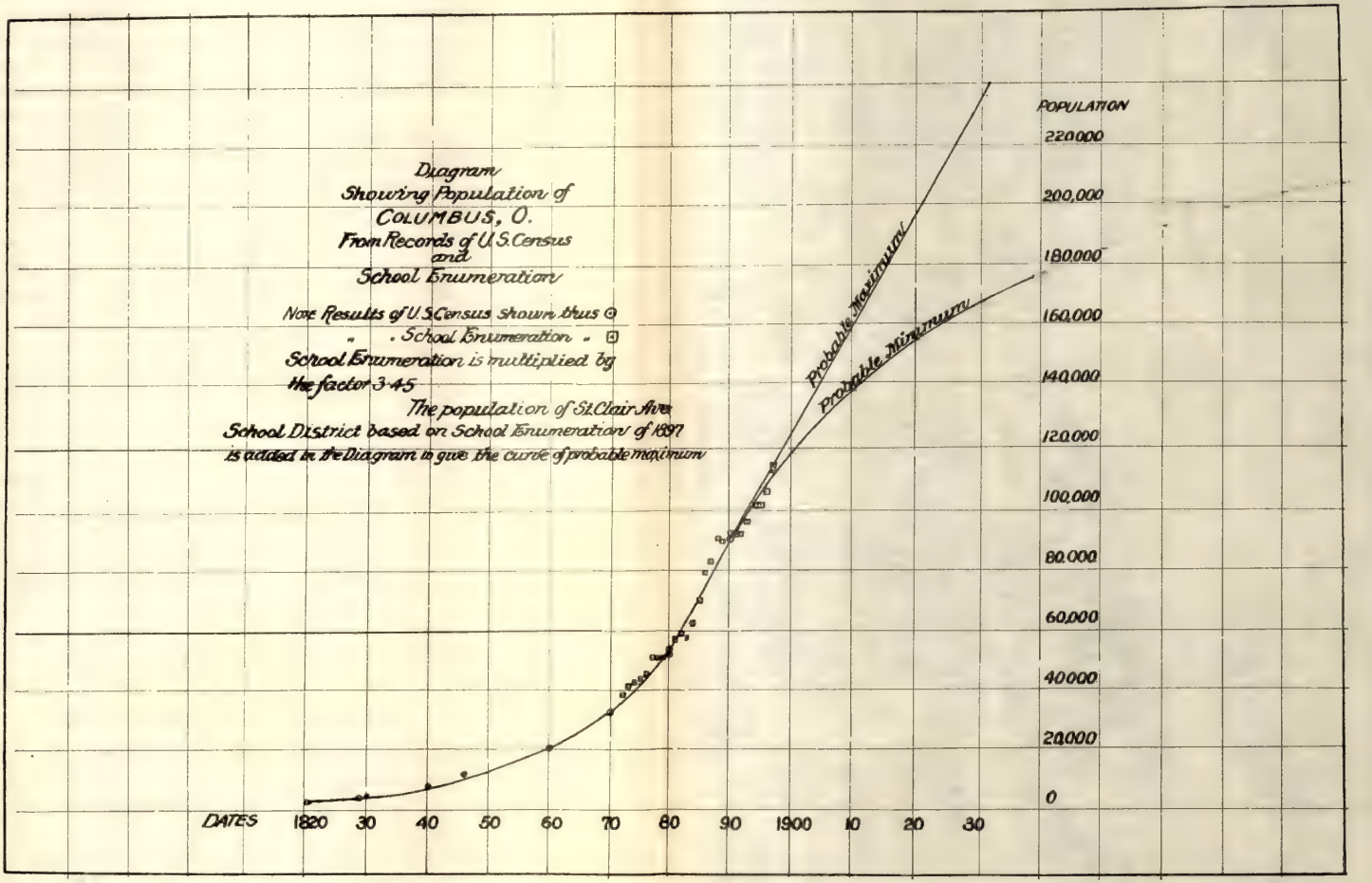


Diagram
Showing Population of
COLUMBUS, O.
From Records of U.S. Census
and
School Enumeration
Note Results of U.S. Census shown thus ⊙
" " School Enumeration " ⊡
School Enumeration is multiplied by
the factor 3.45
The population of St. Clair Ave
School District based on School Enumeration of 1897
is added in the Diagram to give the curve of probable maximum
POPULATION
220,000
200,000
180,000
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
Probable Maximum
Probable Minimum
DATES
1820
30
40
50
60
70
80
90
1900
10
20
30

weather or summer flow of sewage, which, occurring simultaneously with low rates of flow in the river, must be purified by artificial means. It is quite evident that the amount of sewage flowing away from dwellings may be at times materially less than the water supply, a considerable portion of which in summer is used for sprinkling streets and lawns, or is absorbed by plant growth and evaporation.

The natural dryness of the soil does not permit us to believe that the percolation of ground water into the sewers during the summer months can be nearly equal to that of the wet season. On the other hand, it must not be overlooked that the location of the intercepting sewer is such that underground water must necessarily find its way into that sewer to a certain extent, and be delivered to the purification works.

Taking all these facts into consideration, we have concluded, after careful reflection, to place the average amount of daily flow of sewage from the entire city at the present time at 15,000,000 gallons during the summer months, with a probable maximum of 20,000,000 due to the infiltration of ground water, and from occasional storms in dry weather.

Data do not exist for the determination of the length of time each season that the sewage will have to be treated. Unquestionably the variation between different seasons will be great ; but for the comparative purposes of this report, we have estimated that an average of 15,000,000 gallons of sewage will have to be purified daily for six months of each year, and that the plant should have capacity for purifying 20,000,000 gallons daily, without reduction in the efficiency of the purification.

THE EXCLUSION OF STORM WATER.

Suitable automatic storm valves have been designed to control the admission of flow from the main sewers of the city into the intercepting sewer. These valves are so arranged that by the increase of flow of the city's sewers, a float is raised which operates to close the opening into the intercepting sewer, and thus discharge the diluted rain-water sewage of such times directly to the river.

These valves may be so designed that the flow may be partially or wholly cut off at any point desired, and thus latitude may be given in adjusting the relief of the intercept-

ing sewer to the different sections of the city. It is suggested, that if desired, these valves may be so arranged that the sewers in the lower part of the city shall be first cut off from the intercepting sewer in case of storm, while that portion of the intercepting sewer lying along the banks of the Olentangy may be the last to be allowed to overflow to the river. Certain districts may be favored at the expense of others, depending upon the quantity or quality of the sewage they produce.

The importance of thus excluding the water of the more severe class of storms cannot be overestimated. To permit the purification works to receive the water from all rainfalls would be impossible ; to purify the water even from ordinary storms would so increase the cost and magnitude of such works as to place them out of practical consideration. The necessity of such purification is not apparent, as at the time of such rainfall, the flow of the river will be temporarily increased, and will probably dilute the sewage reaching it.

At such times in the dry season as very light rainfalls occur that do not raise the river materially, it is expected that they will be largely absorbed by the natural dryness of the soil, but such portion that may reach the sewers may be purified by the reserve capacity of the works with, of course, a less degree of efficiency for a short period. The intercepting sewer has a capacity equal to a very considerable amount of storm water in addition to the sewage which it ordinarily carries, and arrangements may be made by which it can carry its full capacity in time of storm ; while at its southerly end a diversion sewer to the purification works may be provided with automatic valves to admit as large an amount of this flow as can be cared for, the remainder being emptied directly to the river at the present outlet of the intercepting sewer.

THE QUALITY OF THE SEWAGE OF COLUMBUS.

From what has been said of the quantity of the sewage of Columbus, it may be gathered that in quality it is more than ordinarily dilute. To an average water supply of 117 gallons per capita is added 54 gallons of other water, mainly from subsoil drainage, making a total observed flow of 181 gallons per capita daily for the central district.

Samples taken from the intercepting sewer at the time the

gaugings were made, have been analyzed by Prof. N. W. Lord, of the Ohio State University.

ANALYSIS OF SEWAGE OF COLUMBUS.

TAKEN FROM THE INTERCEPTING SEWER FEB. 21ST TO MARCH 5TH, 1897. BY PROF. N. W. LORD, OHIO STATE UNIVERSITY. PART PER 100,000.

Date.	Free Am.	Alb. Am.	Chlorine
February 21	0.6600	0.4100	3.00
" 22	0.4640	0.2980	2.80
" 24	0.4780	0.2800	3.00
" 25	0.3620	0.2040	2.80
" 26	0:3620	0.3360	2.60
" 27	0.5140	0.4800	3.20
March 1	0.4840	0.2260	3.00
" 2	0.6400	0.4780	3.20
" 3	0.5180	0.4960	3.60
" 5	0.5980	0.5500	3.80
Average	0.5080	0.3780	3.10
Average Am. sewage as found in Lawrence, 1896	4.3300	0.7900	9.860

Taken into consideration with the water supply, the porous nature of the soil, and the use of the combined system of sewers, we think it is fair to assume that the sewage of the city of Columbus, as it will be received at the purification works, will be at least twice as dilute as the ordinary sewage from American cities, and four to five times as dilute as the sewage of English cities of the same general character.

The manufacturing interests of the city of Columbus are not so numerous nor of so special a character as to render the sewage different from the average sewage of American cities of the same class. The sewage of Columbus is of marked alkalinity, and it is believed that it will yield readily to all the ordinary forms of purification without a special previous treatment.

DISPOSAL BY DILUTION.

Up to this time the sewage of Columbus has been emptied directly into the Scioto river, in the attempt to dispose of it by dilution. In the wet season this process seems to be satisfactory. There is no indication of nuisance or cause of complaint, nor does it appear that there are any water supplies drawn from the river, or likely to be taken from that source,

for many years to come, which are liable to contamination from this cause.

The first water supply below Columbus on the Scioto is at Circleville, where a population of about 7,000 persons draws its water from a filtering gallery on the banks of the Big Darby, a tributary of the Scioto, at a point just above its junction with that river, but stationed within the Scioto valley bottom. The distance from Columbus to Circleville is about thirty miles.

At a point fifty miles below Columbus the city of Chillicothe, with a population of about 15,000, draws its supply from a large well, sunk in the river gravel about 150 feet from the banks of the river, from which it is separated by a railroad embankment.

In both of these cases the supply is drawn from the percolating waters of the soil of the surrounding valley, rather than from the river itself. It is possible that the time may come when, owing to the growth of these cities, their enlarged demands for water, and the increasing quantity of Columbus sewage, steps should be taken to insure the safety of their supplies; but it is evident that in the natural order of events it will not be for many years to come.

Dismissing this consideration for the present, we come to the question of actual nuisance, and the danger to health, to the residents of the valley and the lower portion of the city from the pollution of the Scioto river by the sewage of Columbus.

The question whether or not sewage may be properly discharged into a given river, not immediately used for water supply, is decided by the degree of nuisance that will be caused by its pollution. This nuisance is occasioned by the odors of putrefaction and the unsightly appearance of the river, especially at low stages, from floating or stranded sewage matter. Putrefaction occurs inevitably when there is not enough dissolved oxygen in the water to promote the nitrifying process. Up to a certain point with an admixture of fresh water, enough dissolved oxygen is available for the purpose, but when once exhausted, the nitrifying process is retarded, or altogether ceases, and obnoxious gases are generated. There is, therefore, a definite limit or proportion of fresh water, which must be properly mingled with the sewage in

order to rapidly and efficiently purify it. Where this amount is available no more economical or rapid method of purification can be found.

The amount of fresh water thus required can not be stated in fixed terms with satisfaction. In shallow streams of low velocity, in lakes or still water, it is greater than in large streams of rapid flow. The fact that all sewage is not similar in character, often prevents the rates of dilution in one locality from being satisfactory in another. A general statement, however, may be made as follows : It has been found by experience that a rate of flow, in running streams, of from three to seven cubic feet per second, can satisfactorily purify organic waste from a thousand persons, the maximum being applicable in shallow, sluggish streams into which a highly concentrated sewage is poured, while the minimum might be used in a rapidly flowing river of considerable depth and with sewage rather dilute. As before stated, the Scioto river has a flow during the six wet months of the year, of about 600 cubic feet per second ; allowing that a flow of three cubic feet per second would be a satisfactory dilution, we have a population of 200,000 people whose sewage could be efficiently purified in such a stream. In certain months, such as January, February and March, the average flow of the river has been much greater than that given, while in other months of the wet season, there are intervals of several days when the flow may drop to 250 cubic feet per second. At such times a greater ratio of dilution is necessary, and it is evident that with four cubic feet per second, the number of people which could be safely served drops to about one-half of the present population. It is evident that even in the wet season a portion of the sewage at certain short intervals must be purified by other means than dilution. In the dry months of the year, from the last of May until the last of October, the conditions of flow are unsatisfactory. During three months of 1897, an average flow of about 31 cubic feet per second was found at Shadeville, as gauged by Prof. Brown, of the Ohio State University, for the State Board of Health. Considering the shallow stage of the river and its unsatisfactory velocity, a dilution ratio of seven cubic feet per second per 1,000 persons would not be any too effective for such a season.

Upon this basis, during three summer months of 1897, the

Scioto river was capable of purifying the sewage from a population of only 4,430 persons. When it is remembered that about 90,000 persons were pouring their foul wastes into such a stream, the result can be imagined.

For the purpose of fully illustrating the data collected so far, we have compiled a diagram, showing the observed stage of the Scioto river upon a gauge near the site of the outlet of the intercepting sewer, and for the purpose of ascertaining the quantity passed with each stage of the river at this point, we read simultaneously the height of water upon the crest of the State dam, from which the computed flow could be obtained in cubic feet per second. Upon the diagram is plotted at the various stages of the river the number of persons whose sewage can be efficiently purified at the various readings of the gauge and with varying ratios of dilution, dependent upon the physical condition of the river.

It has been suggested that dilution conditions could be had for the entire year by storing water in reservoirs in the Scioto river above Columbus, to regulate and render uniform the flow of the river below the city. To illustrate the impracticability of this suggestion, it may be stated that the water stored in the reservoir now proposed for the new water supply, and estimated to contain 1,627,000,000 gallons, would afford dilution at the rates permissable, and for a period of four months for less then 3,000 people. (See Plate opposite page 24.)

From a study of the data thus collected, we conclude:

1st. That it will be necessary for the city of Columbus to establish and maintain a sewage purification plant of sufficient capacity to purify the sewage of the entire population.

2d. That for a considerable portion of the year, depending upon the stage of the Scioto river, the operating expenses of such a plant may be materially reduced by taking advantage of all the dilution that can be furnished by the Scioto river at a reasonable ratio.

3rd. That such ratio for present purposes may be placed at not less than four cubic feet of fresh water per second for the sewage of each 1,000 persons.

4th. That the sewage disposal plant should have a high efficiency for purification, owing to the fact that there exists no sufficient summer flow in the river for effluent dilution.

We will next consider the different available methods by which artificial purification of the city's sewage may be satisfactorily effected.

INTERMITTENT FILTRATION.

No sufficient area of suitable soil has been discovered upon which plans and estimates might be based for a project for purification by intermittent filtration alone. A tract of land not less than 200 acres, of very porous soil would be necessary for such a project. If the soil was not of the most desirable character, this area would have to be increased to 300 or 400 acres.

The English farm, owned by the city, does not possess a soil suitable for this purpose. A number of test pits sunk to the depth of five feet or more systematically over its area, developed the fact that the soil was, for the most part, a heavy clay, mixed in places with boulder, gravel, and in the lower layers with a small quantity of sand. Something might be done to improve the character of the soil by trenching, but taken at its best we do not believe that a greater quantity than 1,500,000 gallons of sewage could be regularly purified upon its area, even after considerable expenditure for preparation had been made. Some attention has been given the question of burning the clay subsoil into ballast, but nothing satisfactory has been developed. We have been unable to find a use for this land, (consisting of 77 acres) in connection with the purification works, other than as a possible site for some of the chemical precipitation projects, and even for this purpose it has marked and expensive disadvantages.

The most favorable tract of land so far discovered for intermittent filtration, has been a location on the farms of Charles Miller and Henry Schwenker, on the Jackson pike, near the township line of Franklin. With a very considerable expenditure for stripping the surface soil, an area of 75 or 80 acres of porous sandy gravel may be uncovered. Another tract, consisting of about 40 acres in connection with the broad irrigation area, discussed under Project No. 1, has been discovered.

It being out of the question to consider these tracts for intermittent filtration alone, they have been combined with other projects. Sand does not exist in any quantity in the Scioto valley ; the best building sand used in the city comes

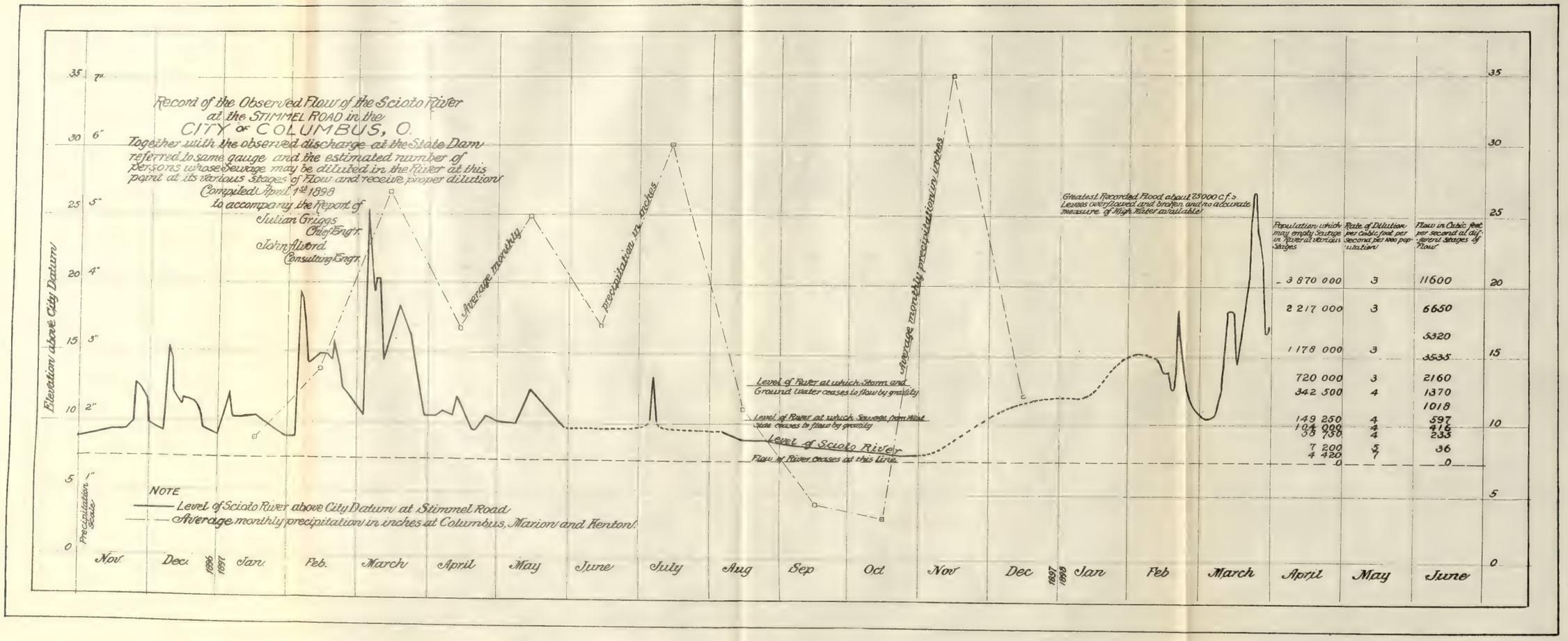
from Lake Erie, and costs about $1.00 per cubic yard delivered. The valley contains bank sand in small amounts here and there, but in pockets only. The characteristics of the river gravel are its coarseness and admixture with clay or sandy clay.

There are extensive beds of this material, but overlaid in almost every instance with a heavy layer of clay and loam, and presenting uneven surfaces; the more level tracts of land at the botton of the valley or on the first river terrace, are invariably composed of either a dense black loam or a thick bed of impervious clay, to the depth of five feet or more.

PROJECT NO. 1.

BROAD IRRIGATION COMBINED WITH INTERMITTENT FILTRATION.

The first and earliest consideration of the problem has been devoted to land methods of disposal. The failure to discover any large area sufficient for intermittent filtration alone, has however developed several available tracts of land for broad irrigation, or broad irrigation followed in small proportions by intermittent filtration. Nearly twelve square miles south of the city, have been prospected and studied. A considerable proportion of this area has been carefully examined by means of test pits and surveys and data on the character of the underlying soils, flood waters, and land values have been secured and compiled. The tract of land finally selected for broad irrigation lies to the east of the Scioto river, between it and the Columbus feeder of the Ohio canal. The tract is about 3½ miles long northerly and southerly, and a third of a mile broad, consisting of bottom land, between the river and the rising ground east of the canal; its northern end is about 2½ miles south of the city limits, while its southern end extends nearly to Shadeville. It will probably be necessary to acquire 1,588 acres, of which 562 acres will not be available for the purpose of disposal, owing to its high


Record of the Observed Flow of the Scioto River
at the STIMMEL ROAD in the
CITY OF COLUMBUS, O.
Together with the observed discharge at the State Dam
referred to same gauge and the estimated number of
persons whose Sewage may be diluted in the River at this
point at its various Stages of Flow and receive proper dilution
Compiled April 1st 1898
to accompany the Report of
Julian Griggs
Chief Engr.
John Alford
Consulting Engr.
Elevation above City Datum
Precipitation Scale
Average monthly precipitation in inches
Level of River at which Storm and Ground Water ceases to flow by gravity
Level of River at which Sewage from West Side ceases to flow by gravity
Level of Scioto River
Flow of River ceases at this line
Average monthly precipitation in inches
Greatest Recorded Flood about 25000 c.f.s.
Levees overflowed and broken, and no accurate measure of High Water available
NOTE
Level of Scioto River above City Datum at Stimmel Road
Average monthly precipitation in inches at Columbus, Marion and Kenton
Nov
Dec
1896
1897
Jan
Feb
March
April
May
June
July
Aug
Sep
Oct
Nov
Dec
1897
1898
Jan
Feb
March
April
May
June
Population which may empty Sewage in River at various Stages
Rate of Dilution per Cubic foot per second per 1000 population
Flow in Cubic feet per second at different Stages of Flow
3 870 000 3 11600
2 217 000 3 6650
5320
1 178 000 3 3535
720 000 3 2160
342 500 4 1370
1018
149 250 4 597
104 000 4 416
58 750 4 235
7 200 5 36
4 420 7 0
0

elevation and uneven character. It is thought that about 45 acres can be rendered available for intermittent filtration at a reasonable expense, while 981 acres will be devoted to broad irrigation, or irrigation where cropping can be practiced in connection with the purification.

With an estimated maximum flow of 20,000,000 gallons in 24 hours, it is found that about 4,000,000 gallons can be cared for upon the intermittent filtration area at the rate of 100,000 gallons per acre per day, for brief periods including time of rest, while the remaining quantity would amount to 16,240 gallons per acre per day on the cropped area. Of the normal or average flow of 15,000,000 gallons per acre per day, about 3,200,000 gallons can be well purified on the intermittent filtration area during dry weather, leaving the remainder to be applied to the land at the average of 11,450 gallons per acre per day. This applied intermittently would amount to about ⅞ of an inch in depth over the whole area every other day, a very considerable and unusual amount to apply in this manner. Only one consideration will allow us to think of it as a practical operation, and that is, that at all seasons of the year, except the dry weather of summer, the sewage of Columbus may be largely if not wholly purified by the Scioto river. In the dry weather when the Scioto can effect but a small amount of purification, the sewage farm will be able to take its maximum of irrigation. In order that it may be fully understood how great a rate of flow this will be, a list of some 30 of the larger sewage farms have been compiled, with notes on the character of the soil and the rate of flow, it being observed, of course, that these are annual average rates of flow and not summer maximum rates :

TABLE SHOWING DATA OF BROAD IRRIGATION FARMS, CHARACTER OF SOIL AND RATE OF FLOW.

	Place.	Character of soil.	Max. gal. per acre per day.
1	Edinburg, Scotland	Boulder clay, drift sand	33,000
2	Paris, France (1st)	Sand and gravel (small areas only)	29,362
3	Croyden, England	Gravelly soil	28,950
4	Framingham, Mass	Sand (intermittent filtration).	23,000
5	Nottingham. England	Light soil	15,500
6	Birmingham, "	Gravel and sand	12,000
7	Berton-on-Trent, Eng	Gravel	11,600
8	Breslau, Germany	Porous	10,397
9	Wimpledon, England	Clay	10,200
10	Paris, France (2nd)	Sand and gravel	9,787
11	Brockton, Mass	Sand	9,000
12	Kidderminster, England.	Loamy	9 000
13	Norwich, England	"	8,000
14	Dantsic, Germany	Porous	7,700
15	Warwick, England	Clay	7,692
16	Wolverhampton	Clay, gravel	7,000
17	Bedford	Porous	6 451
18	9 towns of Eng. averaged		5,521
19	19 " " "		5,128
20	Aldershot, England	Loamy sand	4,862
21	Berlin, Germany (Osdorf)	Sandy	4,800
22	Wrexham, England	Drift gravel	4,520
23	Oxford, England	Sand subsoil	4 500
24	Leamington, England	Gravel	4,095
25	Crewe	Strong clay	4,000
26	53 English towns avr'gd.		3,826
27	Berlin, Ger. (Falkenberg)	Heavy soil	3,622
28	Rugby	Loam	3,570
29	Northampton	Loamy gravel	3,000
30	Doncaster, England	Gravelly	2,962

Assuming that the maximum summer flow in the table is 50 per cent. in excess of the annual average rate, it will be seen that the flow proposed for Columbus sewage will come between the 13th and 14th place on the list for the average flow, and between the 7th and 8th place for the maximum flow.

It will also be noted that only two places upon the list above these can be classed as clay or loamy soil.

The soil of the area selected for Columbus is for the most part a deep rich loam, overlaying in some portions of the area a sandy gravel, and in others a clay subsoil, which in turn overlays the river gravel. On those portions of the lands nearest the river the loamy soil is over five feet in depth above the gravel, while near the first river terrace along the eastern edge, the gravel and sands rise in some places to within two or three feet of the surface. The most available lands of this latter character have been set aside for intermittent filtration.

Taken as a whole, this tract of land is better adapted to

the purpose of sewage farming, or what is more important, sewage purification, than other tracts nearer the city, such for instance as was mentioned by Col. Waring in his suggestion of 1890; and it has also been found that the cost of conveying the sewage the greater distance to the site is more than balanced by the decreased cost of the lands further from the city, and their greater adaptability to the purpose.

It would be very desirable, if it were possible, that the area set aside for intermittent filtration be larger, but suitable lands for this purpose in any greater area than that mentioned have not been discovered; for this reason, the farm project as outlined, can not be considered as a method of sewage disposal, except in the dry season of the year. If for any reason the State Board of Health should require in the future that the sewage of Columbus be purified a larger portion of the year than has been estimated upon, it would be necessary, in order to obtain the required efficiency in wet weather, to increase the intermittent filtration area to about 150 to 200 acres, by constructing artificial intermittent filtration beds at an expense which will add at least 50 per cent. to the first cost of the entire project herein estimated.

In making provision for the future growth of the city, extensions in area will probably have to be made in this manner. The higher lands of the area not available for broad irrigation seem to promise some deposits of sand and gravel, not entirely of a suitable character, but which nevertheless, with some care in selection, may answer for construction of this kind.

In selecting a project for broad irrigation, the highest duty of the land has been counted upon, and in order that this duty may be obtained, unusually complete underdrainage has been estimated for in every part of the area. The entire underdrainage system should be laid deep, so as to be wholly in the porous sand and gravel underlying the surface loam; the main underdrains will range from 12 to 24 inches in diameter, and are proposed to be well protected at their outlets by sensitive self-closing outlet gates to prevent the flooding of the farm from high water in the river. Branches of 6-inch farm tile, deeply laid, are to be spaced eight rods apart over the entire area. It has been found by experience on English sewage farms that for every three gallons of sew-

age applied to the surface, about two gallons will flow off in the underdrains, the remainder being absorbed by evaporation and vegetation. It is believed in the hot dry weather of this climate that even this proportion will not find its way again to the river.

The sewage will be brought to the farm from the proposed pumping station by means of a cast iron main 42 inches in diameter, for the greater part of its length ; this main will be laid to and through the site a distance of about six miles. It will be laid near the west side of the canal at such an elevation that a considerable area of bottom land may be irrigated by it before reaching the proposed farm. The area of this available land is estimated at about 450 acres, and hydrants for the purpose of utilizing it may be set in the main pipe at the time it is laid. The lift at the pumping station when the maximum quantity of sewage is being delivered at the farm, will be about 36 feet, and the annual cost of pumping based upon the quantity assumed, is shown in the subjoined estimates. See Plates C and D, Project No. 1, in back of pamphlet.

The distribution system upon the farm itself will be by elevated canals located upon the higher portions of the area, and by means of numerous sluice boxes in these main canals the sewage may be diverted to secondary ditches, or to the fields themselves, which should be prepared by ridging so as to be flooded to the best advantage.

It has been thought desirable in hot summer weather with certain crops to avoid flooding the different areas in day time, as with bright sunshine injury would result ; for this purpose the main carrier ditches have been made very ample in capacity, so that a certain amount of storage in them may be available, and to further supplement capacity in this direction, some twelve shallow reservoirs about two acres in area each are provided, to store the day flow and allow of night flooding ; these reservoirs are only widened sections of the ditches.

The sewage in being led over the farm by the main carrier canals, is made to pass from higher to lower levels by weirs or small adjustable dams, by means of which erosive action is avoided and the quantity stored in the reservoirs and canals is regulated and drawn off as may be desired.

The quantity passing to various parts of the farm can

thus be measured and adjusted in proportion to the area, so that after a little experience each section can receive that quantity which is found best adapted to the depth and character of its surface soil. The method of irrigating the sewage upon the land should be intermittent ; that is, a certain section of the farm having received a uniform flooding not to exceed one inch in depth, should then be allowed to soak up the liquid and dry out to the depth of a few inches, before being again flooded. With reference to this point, we can not do better than to quote from Mr. Bailey Denton's recent work on sewage purification. Mr. Denton, who is an eminent authority in England on this subject, says :

" With surface irrigation, no single dressing of liquid to be productive of benefit should exceed an inch in depth, and directly the quantity applied to an acre of land exceeds that depth, which is equal to 100 tons, the surplus is positive waste. All land laid out for sewage irrigation has sloping surfaces, which cause the liquid to run down to the lower portions of the surface and to rest there in slacks and hollows until it is absorbed and evaporated, doing mischief in the meantime. The farmer who pays rent for the land with sewage soon finds this out. He knows that he can not profitably apply more than 20,000 gallons per acre at a dressing except to fallows bare of vegetation, which no sewage farmer ought to have in the growing season. Experience in fact goes to prove that sewage, let its intrinsic value be what it may, directly it be delivered to land by way of surface irrigation without that systematic arrangement which will secure regularity of distribution in the quantities that will be beneficial, ceases to be of any value at all."

The best crops suitable to this climate and its conditions can only be determined by experiment. In general, it may be said that the crops now grown in the vicinity can be grown with greater certainty, although some crops are not evidently adapted to excessive moisture at all seasons, while others flourish under such conditions. Italian rye grass is such a crop ; the cabbage tribe is greedy of sewage; most of the root crops do well where the land is well drained ; while cereals and pulse crops, instead of being benefited by its direct application to them while in growth are damaged by the increase of straw at the expense of the grain ; potatoes and turnips are also injuriously affected in a like manner.

Hay crops, especially the coarser kinds, are thrifty, mangolds and other roots of similar character flourish ; carrots

and parsnips do well in sandy soil ; corn is grown to advantage upon some beds, such as Plainfield, N. J., and Marlborough, Mass., but judgment must be used in advantageously irrigating such crops. Where market gardening is carried on upon sewage farms, the ridge and furrow system is used, and the vegetables planted upon the ridges do not come in contact with the sewage. It may be mentioned that the vegetables from the sewage farm of Berlin command a premium in the Berlin market, owing to their extra quality and fine appearance.

OBJECTIONS.

It may be gathered from the above statement that experience in ordinary farming does not always fit one to become a successful sewage irrigation farmer ; and it must be evident that the management of so large a farm as that proposed for the purification of the sewage of the city of Columbus is a business enterprise involving capacity of the highest order. The question of the municipal management of such enterprises is too large a question to be discussed in this report ; but it can be safely assumed that complete success or complete failure of such an undertaking, and all the intervening shades of partial success or failure may result from the management. When one considers the thrift and self denial requisite to make ordinary farming successful in this country in the past decade, it is evident that it will not be wise to cherish any illusions as to the financial success of a municipal sewage farm. One of the greatest difficulties connected with the management of sewage purification in any of its forms, is the temptation on the part of the manager of the works to show a low annual cost of operation at the expense of efficiency in purification. Efficient purification costs money and does not always show in annual reports. Cost does show and vitally affects the tax payer ; consequently such works are often called failures from this cause. Sewage farming or broad irrigation is peculiarly liable to this objection. In the effort to make the farm pay, the purification of the sewage becomes a secondary consideration, and is often notoriously neglected.

The project for the purification of sewage by irrigation is also open to the objection that it requires a large immediate outlay for land, force main, underdrainage, preparation of

fields, buildings, stock, tools, etc., before purification can actually commence. It is true that the full amount of land will not have to be prepared at once, but the commencement of this project will require larger initial outlay than any other considered. A further objection is found, which is common to all the methods discussed, but is especially marked in the case of broad irrigation; this is, that the excessive dilution of the sewage requires a much larger amount of land than is needed by other localities where the sewage is collected by the separate system; and as land is a large item of expenditure for broad irrigation, the practicability of this project is very seriously hampered thereby. Were the sewage of Columbus collected by the separate system and of the usual concentration, the customary rule of one acre to each 200 persons could doubtless be approximately followed, and 575 to 600 acres might answer all present requirements, but the capacity of land in sewage farming is governed by the quantity of moisture which can be absorbed without injury to the crop, and not by the amount of organic impurity that the moisture contains, and so it happens that the 981 available acres estimated upon, is really a minimum of requirement for present uses only.

Some of the advantages of this project are as well defined as the objections. The sewage farm affords in the dry season a satisfactory mode of purification, for it is then in most need of the irrigation and can assimilate and purify the maximum quantity of sewage; in the wet weather, when the capacity of the farm is limited, it is not needed by reason of the opportunity then afforded for the dilution of the sewage in the Scioto river by the method now in use.

It has been further urged that the land and its improvements are good assets, and in case new or improved methods of sewage purification should be adopted, can be sold for all or more than they cost. While we do not consider that this advantage has great weight, we are willing to admit that it is in many respects an advantage and is entitled to mention.

After very careful consideration, we have placed the running expense of the farm at about 25 per cent. more than the income. This project is the most difficult one to estimate in this respect. Taking all things into consideration, we have

preferred to be upon the safe side, and have assumed a net annual loss upon the actual operation. We see no reason why, with unhampered efficient management, the farm should not pay running expenses. Experience in this respect is as varied as the number of localities. The Berlin farms of 22,000 acres, which pay about 2 per cent, upon the capital investment, besides running expenses and maintenance (not including pumping), are usually quoted as a notable example of financial success, but many other farms not so favorably situated do not show as good a balance sheet.

METEOROLOGICAL INFORMATION TAKEN FROM THE 13TH ANNUAL REPORT OF THE OHIO CLIMATE AND CROP SERVICE.

Annual mean temperature, 1895	$51\frac{6}{10}°$.
Normal " " "	52°.
Maximum temperature, 1895	99° June 3rd.
Minimum " "	–8° February 19th.
Yearly range	106°.
Precipitation, 1895	39.28 inches.
Normal precipitation av. 13 years	38.46 "
Greatest observed in 24 hours	3.33 inches, April 7, '95.
Nunber of days in which .01 inch fell	82.
Prevailing direction of wind	S. W.
Date of last killing frost in spring	March 21, (1895).
Date of first killing frost in fall	October 10th.

	Mean temp.	Precipitation.
January	25.8°	3.28 inches.
February	29.8°	3.86 "
March	35.8°	2.75 "
April	50 8°	2.99 "
May	59.9°	4.22 "
June	69.9°	3.82 "
July	72.4°	3.28 "
August	70.4°	3.12 "
September	64.8°	2.92 "
October	51.1°	2.36 "
November	39.7°	3.20 "
December	32.1°	2.66 "
Average for 13 years	50.1° per year.	38.46 " per year.

PROJECT NO. 2.

CHEMICAL PRECIPITATION COMBINED WITH COKE FILTRATION.

In working out a project for chemical precipitation, it was at once seen that no form of precipitation alone would be satisfactory. The Scioto river below Columbus contains little else in dry weather than the crude sewage of the city.

To remove but one-half of the organic impurity of this flow would accomplish nothing practical towards the lessening of present evils. Chemical precipitation alone can remove only about 60 per cent. of the impurity of the sewage, and is practical and successful only when further effluent purification is provided. Most of the prejudice which exists against chemical precipitation as a method of sewage purification arises from a misconception of its limitations, or of failure on the part of those who have adopted it to provide for the proper purification of its effluents.

The largest example of chemical precipitation in this country is at Worcester, Mass., where for nine or ten years past a population about the same in number of that of Columbus, has been treating a very diluted sewage, now amounting to 15,000,000 gallons daily, by this method. The effluent from these works has been emptied into a stream already badly polluted and incapable of properly purifying it, and the result has been that while the plant itself has given admirable results under most efficient and skillful management, the net result of the attempt of Worcester to purify its sewage has not resulted to the satisfaction of the residents of the towns along the river below the city. Steps are now being taken by the city to further purify the effluent from its works.

The city of Providence, with a population of 150,000, after thirteen years of pains-taking investigation, is at this writing letting contracts for the construction of a chemical precipitation plant of 15,000,000 gallons capacity every 24 hours, the effluent to be emptied into the bay at high tide.

In England, chemical precipitation has had its greatest development. Essentially a country of small rivers, frequent

population centers and high values of land have compelled the adoption of chemical precipitation as the most economical method to pursue in the majority of cases. But in England, in nearly every case, effluents are further treated by rapid filtration upon land, and the Rivers Pollution Commission are requiring land treatment of effluents in all cases now coming before it for approval.

In working out a project for chemical precipitation for the city of Columbus, the most important point to be considered will be the proper treatment of the effluent. Owing to the scanty area of suitable land of a porous nature at convenient distance, two projects have been worked out and estimated ; the first of which is discussed as Project No. 2, and contemplates the filtration of the effluent through coke breeze. This project will necessitate the acquisition of land to the amount of about 60 acres in the immediate vicinity of the proposed pumping station, on the bottom lands of which about 30 acres will be directly necessary for the first installation. The sewage of the west side and from the intercepting sewer will be lifted about 14 feet by the engines of the pumping station, and will pass to the works through a 36-inch main, a distance of a few hundred feet only. The works as shown upon the general plan consist of three buildings, two of which are 50 feet by 80 feet in plan, and the remaining building, an office and labratory, 25 feet by 40 feet. Of the larger buildings, one may contain the chemical store and mixers, while the others should be entirely devoted to the treatment of the sludge, and have installed the necessary sludge presses and pumps.

All the machinery is planned to be operated from the pumping station. The sewage may receive its charge of chemicals by a pipe leading from the chemical house to the suction well of the pumping station, thus giving the centrifugal pumps an opportunity to incorporate it thoroughly with the sewage.

Arriving at the works, additional ingredients may be added in the channel opposite the chemical house, into which the sewage is emptied from the force main ; this channel passes to the precipitation tanks, 40 in number, having a combined capacity of 8,000,000 gallons, or a little more than one-half the estimated average flow. Inlet gates and chan-

nels are so arranged that the sewage may pass into any series of tanks desired or found effective in practice ; the tanks themselves have been made circular in form in order that recent improvements in the removal of sludge may be adopted, if desired.

A clean water pump is provided, with a system of pipes and hydrants located within convenient distance of each tank, so that a small stream of water under good pressure may be used in cleaning them ; the water system is necessary also to keep the whole plant in a clean and neat condition ; occasionally lime water should be used for this purpose. The sewage having settled in a precipitation tank, the effluent passes into a channel and thence to the filter beds. The tanks should be emptied frequently for the removal of the sludge, which is passed into the sludge tank near the sludge house by a system of cast iron pipes and a masonry drain ; thence it is pumped into the sludge presses ; the pressed sludge cake may be buried, or may be used for filling about the plant. The cakes themselves are not offensive, but their value for manure is small where the lime process is used.

The clarified sewage from the precipitation tanks being relieved of its suspended matters, is allowed to flow to the biological filter. These are twelve in number, divided in tanks of one acre each, and consist of crushed coke covered with a layer of gravel about three inches in depth, the depth of the beds being five feet over the underdrains ; the sewage will be distributed upon the beds by half section farm tile laid in the surface of the beds, and thorough underdrainage will be carried out by means of lines of six-inch farm tile thirty feet apart.

The method of working the beds will be to close the valve in the main underdrain, fill the bed from the tile carriers to within a few inches of the top, and allow it to rest at least three hours before emptying. After emptying, a period of about three hours rest should be allowed in which the bed may absorb oxygen, the whole operation occupying about eight hours, and being repeated three times each day, with one day each week out of service.

It is unnecessary to go into the detailed biological explanation of the above operation, which will be more fully treated under Project No. 6. Sufficient to say that a filter

constructed and operated as above described is a true biological filter, favorable to the growth and propagation of that form of nitrifying organism, the presence of which is essential to the oxidation of the organic matter.

The main expense for operation will be for chemicals; lime and sulphate of alumina are recommended, although sulphate of iron will be a valuable alternative. Owing to the dilution of the sewage it will not be necessary to use as large a quantity of chemical as is usual. A chemist should be placed in charge of the plant, and should be constantly employed in studies as to its efficiency. About thirty men will be required to clean the settling tanks, press the sludge and mix the chemicals, and divert the sewage from one filter bed to another.

It is not an exact statement to say that all chemical plants are inoffensive, but it is safe to say that in a well designed and operated sewage disposal plant of any character, no offensive odor will be observed. To accomplish this object it is necessary to observe two principles :

1st. The sewage must be delivered to the plant as soon after its creation as possible, certainly within three hours, as it will be in any well designed sewer system. In this state it resembles dishwater, and is not practically offensive, having only a slight musty odor.

2nd. The plant must be so designed and managed that the purification has been completed before offensive decomposition can set in. To this end, the sewage must be hastened through the various stages of its purification ; the tanks must be frequently and carefully cleaned ; the sludge emptied from them must be pumped and pressed as speedily as possible, and ample facility must be provided for these operations. A false economy which will provide an insufficient force of men and an unintelligent supervision, will speedily create offensive conditions, and bring disrepute upon the system employed, whatever that system may be. (See Plate E for plan of chemical precipitation—Project No. 2.)

PROJECT NO. 3.

CHEMICAL PRECIPITATION COMBINED WITH INTERMITTENT LAND FILTRATION.

This Project is essentially the same as Project No. 2, except in its location and the treatment of the effluent, which is by intermittent filtration on land. After a very thorough investigation of the country to the south of Greenlawn avenue, a suitable tract of land has been located, mentioned under the head of "Intermittent Filtration." With some considerable expenditure for grading and stripping of the surface soil, 74 acres can be made available for rapid intermittent filtration of the effluent from chemical tanks. This involves the maximum rate of 270,000 gallons per acre per day, inclusive of rest periods. It is thought that detailed plans and estimates upon the site are warranted by the porosity of the soil, favorable character of its topography, and its nearness to the city. Additional area for future extension can probably be made available, but with greater proportional expense than that allowed in this estimate, as the material for future extensions of the filtration area will in all probability have to be brought from the higher portions of these and other farms lying about three-fourths of a mile to the west. A very thorough survey has been made of the area in question, and test pits dug regularly over it at distances of 400 feet apart in each direction.

The project will include a 36-inch force main two miles long, leading from the pumping station south along the bank of the river, to the north line of the Miller farm. The force main may be used to irrigate the bottom lands through which it passes, as was proposed in Project No. 1 (Broad Irrigation). Upon arrival at the Schwenker farm the sewage will be chemically treated as described in Project No. 2, passing into precipitation tanks for that purpose precisely as there outlined ; the sludge may be run direct upon the adjacent farm or removed by neighboring farmers, but sludge pressing machinery has been provided for in the estimates, as it will undoubtedly be needed.

The effluent from the precipitation tanks, instead of passing into coke filters as described in Project No. 2, will be led upon the land by canals so arranged as to distribute it to every part of the area. The irrigation lands are divided into beds of one acre each, separated from each other by embankments formed of the top soil, which will have to be stripped from the beds. A thorough system of underdrainage is planned and estimated, of sufficient capacity to allow of the greatest efficiency of the gravel and sand in the beds; the area selected lies sufficiently high above the river to enable the beds to have a depth of five feet above the underdrain.

The remainder of the farms, which will probably have to be purchased entire, may be utilized for broad irrigation, but no estimate has been made for their improvement for this purpose, as the amount of sewage which can be disposed of by this means is so small, and the remainder of the lands of so unfavorable a character, that any considerable expenditure will not be warranted at the present time. There is in the vicinity a tract of land estimated at 600 acres, which might be purchased and utilized for broad irrigation, if it should be found necessary in considering future extensions. Power for the operation of the chemical plant may be derived from an electric motor in the pumping plant, and utilized by means of a transmission line, estimate for which is included in the total. The cost of construction will be large for the chemical plant on this location, owing partially to the long haul from the city for material. The operating expenses will also be greater, both by reason of the inaccessibility of the site and also from the fact that the irrigation area will require more care and attention than the coke filters in Project No. 2.

In determining the size of the force main from the pumping station, it is found that considering the cost of pumping, interest and depreciation, a 42-inch main will be operated for about $2,000 per annum less than a 36-inch main, but the size of 36 inches has been selected nevertheless, in view of the low velocity produced in the 42-inch main with small quantities of flow. (See Plate F for plan of Project No. 3.)

PROJECT NO. 4.

THE FEROZONE POLARITE PROCESS.

The Ferozone Polarite process of sewage purification was first installed at Acton, near London, in 1888, and has been operated successfully since. These works were examined by your consulting engineer while on a visit to England during the first year of their installation, and made a favorable impression. Since that time we understand the system has been put into successful operation in a large number of towns and cities, among which are Huddersfield, with a population of 100,000; Chorley, Sale, Gorton, Willesden, and other places in England. The city of Madison, Wis., has lately contracted to install the system, and the British Government has constructed works which are in operation in Gibraltar, Malta and other places.

The Ferozone Polarite process is a chemical precipitation process, followed by filtration, and differs in method only from that proposed in Project No. 2. The sewage is first treated with the chemical known as ferozone, which is a precipitant and deoderant, and composed largely of sulphate of iron and alumina. After being thus treated it passes to the precipitating tanks, which are of an improved form and fitted with an ingenious method of removing the sludge, which operates without emptying the tank or throwing it out of use, as is ordinarily the case. From the precipitating tanks the effluent flows to a series of especially constructed and prepared polarite filtering beds, the polarite of which is made from magnetic iron ore, so as to form a hard, porous and insoluble substance, which has considerable power of absorbing and giving off oxygen, and does not require to be renewed. The surface of the beds are washed by an upward flow in much the same manner as are the various mechanical filters used in this country.

The sludge is removed, filter pressed and disposed of as described in Project No. 2, and it is claimed that it has a greater value as manure than where lime is used as a precipitant.

Some of the advantages which are claimed for the system are as follows:

1st. The saving in pumping expense over ordinary chemical methods.

2nd. Improved method of handling sewage in the precipitating tanks.

3rd. The small cost of operation.

4th. Small area of land required.

The process of sewage purification as carried on in Europe by the International Sewage and Purification Company, limited, of London, England, is a proprietary process, the rights of which have been recently acquired for this country by the American Sanitary Engineering Company, of Detroit, Mich. The disadvantage of dealing with a proprietary method could be offset if the American Sanitary Engineering Company would give a reasonable guarantee for efficiency and operating expenses, and agree that no royalties or other charges shall be made other than the contract price.

In view of the recent adoption of this system by the city of Madison, Wis., and its extensive use abroad, it was thought desirable to invite the representatives of the company to submit plans and approximate estimates upon their system, based upon the same quantity of sewage and the same general conditions which have governed the plans and estimates for the other projects considered, so that a reasonable comparison might be made. This the company have consented to do, with the results embodied in the subjoined estimates and plans, made by them without seeing the other projects with which they have been compared. (See Plates G and H, for Plans of Project No. 4.)

PROJECT NO. 5.

THE SEPTIC TANK SYSTEM, WITH COKE FILTRATION FOR THE EFFLUENT.

The Septic System of sewage purification is of recent development, and has its origin in Exeter, England, where it has been in use for nearly two years. The first installation covered only one district of the city, but works are now in progress for extending it over the entire city. The system has aroused a very wide interest among sanitary engineers, by reason of the development of radically different methods of propagating the nitrifying organism from those heretofore in use. The Septic system brings into action what are known as anerobic bacteria, so called because they thrive without light or oxygen, in contradistinction to aerobic bacteria, whose cultivation is now comparatively well understood. In intermittent filtration, aerobic bacteria are cultivated in sand beds, whose stored oxygen is frequently renewed. Anerobic bacteria, on the other hand, require the sewage to remain for some time in closed air tight tanks, in order to afford the most suitable environment for the propagation and active work of this form of organism. Covered tanks are provided, capable of holding the sewage at least 18 hours, during which time active nitrification takes place, and at Exeter the amount of oxidizable organic matter in solution is reduced by 38 per cent., the free ammonia by 26.9 per cent., the albuminoid ammonia by 17.5 per cent., and the suspended solids by 55 per cent., the condition of the remaining organic matter rendering it more easily broken up and further purified. The effluent from the septic tank is then passed into a biological coke filter, similar to those described in Project No. 2, for chemical precipitation.

The wide interest which has been taken in this system in England, and the high standing of the chemists who have examined its working and pronounced favorably upon its capabilities, warrants us in considering it in connection with the Columbus problem.

Enough data have been published to enable us to understand in a general way the principles which must govern its

use, and general plans have been drawn, estimated and compared with other projects. It will be readily understood, however, that it is impossible to give to a new and unfamiliar process the same relative standing as should be accorded to older and well understood methods of sewage purification. In laying out this system for Columbus, we have provided 24 hours' rest for the average flow, and 18 hours' rest for the maximum flow. At Exeter the effluent has been passed through coke breeze filters five feet in depth for the remainder of the purification, at the rate of flow of about 660,000 gallons per acre per day. The purification obtained in the coke filters, at the rate of flow based on oxygen absorbed, is given by Mr. Dibdin in his report at 72.4 per cent. of organic impurity removed. As the sewage of Exeter is shown by the analyses to be about three times as concentrated as the sewage of Columbus, it is thought that this will fully correspond to a purification of 95 per cent. upon the whole plant for this locality.

In the plan for Columbus, as contemplated, the sewage first passes into an open masonry channel between the tiers of tanks, 32 in number and capable of holding each 500,000 gallons. Suitable appliances are provided for annually removing the mineral matter which will accumulate at the bottom of the tank, and the gas which may be burned. The overflow from the tanks is then led to artificial coke filter beds similar in all respects to those described in Project No. 2, (Chemical Precipitation) comprising 16 acres of effective area five feet in depth.

One of the most interesting features of the Septic System is the positive determination of the disappearance of the oxidisable organic matter, the sewage in the tanks at Exeter being cleaned of relatively small amounts of mineral residue only about once a year. The minimum time required to fill a tank with this residue has been estimated at three years. It is needless to say that the sludge in so concentrated a sewage as that of Exeter, would create under ordinary circumstances, several times the quantity each year that these figures represent, thus showing the complete disappearance in gaseous forms of the larger portion of the sludge.

From the subjoined estimates it will be found that the first cost of the system is large; and while the running ex-

pense is comparatively light, the capitalized cost does not compare very favorably with other methods. It may be remarked that as at Exeter, automatic valves may control the filling and emptying of the filter beds, and thus reduce the running expense. This automatic device is a proprietary article.

The expensive character of the tanks required for this system would seem to argue against its general introduction in the larger cities like Columbus, and especially where the separate system of sewers does not exist. There must be many places, however, where it can be successfully and economically used when conditions are favorable. Certainly it is an addition to the resources of the sanitarian, and will in time no doubt take its place among the accepted and well tried methods of sewage disposal. (See Plate J for Plan of Project No. 5.)

PROJECT NO. 6.

MECHANICAL SCREENING AND COKE FILTRATION, FOLLOWED BY INTERMITTENT FILTRATION ON LAND.

The success of coke biological filters at Sutton, England, and the experience gained by the filter operated during 1895, 1896 and 1897, by the London County Council at Crossness, and still in operation, has more than confirmed the rapid filtration experiments of the Massachusetts State Board of Health, and has given us a practical method of preparing artificial biological filters for rapid filtration. This method is warmly advocated by no less eminent authority than Mr. W. J. Dibdin, chemist to the London County Council, who now proposes to filter the entire effluent from the chemical plant of London before emptying it into the Thames; a total quantity of 180,000,000 gallons every 24 hours. Coarse grain filters have been investigated in this country, and with results quite satisfactory in their way, so that it can not be said that such filters are a new or untried process, but rather an improved way of using old and well tried methods to obtain larger practical results. The essential features of this

method of operating a coarse grained biological filter are to hold the sewage in contact with the grain of the filter, rather than to allow it to flow through the filter by its own head, thus overcoming the difficulty often occasioned in coarse grain filters of too rapid flow. This result is accomplished by fitting the underdrain with suitable valves and placing the material for the filter in water-tight compartments. The filter then being flooded with the sewage to the level of the top of the filter material, is left for some hours in a state of rest, the degree of purification depending upon the length of time contact is maintained in this manner. The valves are then opened, the purified effluent drawn off, the filter allowed to absorb a fresh supply of oxygen, when it is filled again with sewage.

In the filter operated by the London County Council at Crossness, this operation is performed three times in 24 hours through one acre of coke breeze three feet deep, with a total removal of about 80 per cent. of organic impurity. The Exeter coke breeze filters are operated in the same way four times in 24 hours, with a total reduction of 72 per cent. of the organic matter. A three months' operation at Sutton gave as the result of a rate of flow of 773,000 imperial gallons per acre per day, through a combined burnt ballast and coke breeze filter, of 86½ per cent. of organic matter removed from a sewage several times more concentrated than that of Columbus.

The second essential feature of a rapid biological filter is the character of the grain. After preliminary trials with burnt ballast, fine gravel, coarse sand, and other materials, Mr. Dibdin concluded that coke breeze gave the best results ; coke being a porus material, retains air after being submerged, and thus furnishes the environment required by the nitrifying organism. This bacterial action is, however, evidently accomplished upon the surface of the grain and not upon its interior, for upon breaking a piece of coke which has been submerged for some time, it will be found quite dry beyond about one-eighth inch from its outer surface.

It is evident from what has been said that a rapid biological coke filter is operated differently from an ordinary sand filter, in that its cubical contents rather than its superficial area determines its capacity. In an intermittent sand filtra-

tion bed the top layer of sand is found to do the largest portion of the active work of the filter, and is therefore relatively important. In a rapid coke filter of coarse grain, on the other hand, the surface of the grain evidently replaces the surface of the sand filter in furnishing the proper habit for the nitrifying organism. One of the great advantages a coarse grain filter has, is the far greater rapidity with which the air enters it after its rest period begins than is the case with sand.

The coke filter operated at Crossness consists of coke breeze, three feet deep and one acre in area. The following amounts of sewage and the analysis of the effluent and filtrate, are taken from the report to the Main Drainage Commission of the London County Council, in November, 1896 :

TABLE SHOWING RESULTS OF ANALYSIS ON THE EFFICIENCY OF A COKE BREEZE FILTER,

MADE BY MR. W. J. DIBDIN, CHEMIST TO THE LONDON COUNTY COUNCIL.

1 Acre of Coke Breeze 3 feet Deep.

Date.	Quantity of effluent passed daily per acre. Average of seven days.	Average oxygen absorbed in four hours. Grains per gallon.		Average albuminoid ammonia. Grains per gallon.		Average nitrogen as nitrates. Grains per gallon.		Average purification effected, as determined by oxygen absorbed.
		Effluent.	Filtrate.	Effluent.	Filtrate.	Effluent.	Filtrate.	
1894.								Per ct.
April 7 to June 9....	500,000	4.096	0.856	0.416	0.095	0.1280	0.2378	79.3
Aug. 3 to Nov. 9	600,000	3.608	0.730	0.396	0.113	0.0223	0.1414	79.6
1894. 1895. Nov. 16 to March 2..	1,000,000	4.113	0.935	0.382	0.114	0.3956	0.6990	77.5
1895. April 8 to April 20..	1,000,000	3.512	0.884	0.360	0.102	0.1431	0.770	75.4
May 4 to Sept. 28....	1,000,000	3.233	0.638	.....	.....	.....	.....	80.7

In connection with this result, Mr. Dibdin says :

"That sewage, especially if previously clarified by precipitation, may be purified to any desired degree; the actual amount of purification depending :—1st. Upon the length of time during which the effluent is allowed to remain in contact with the filter; and 2nd. The length of time allowed for aeration. If a reduction of 75 per cent. in the oxidizable organic matter in solution be considered sufficient, the quantity that can be treated per diem on one acre of coke breeze under these conditions, is 1,000,000 gallons (Imperial). A point of the greatest importance is the fact that the filter

was able to do its work satisfactorily during the exceptionally severe weather of January and February, 1895; a thin coat of ice was formed on the surface, but the filtration proceeded without intermission, the only noticeable change being the decreased production of nitric acid."

The report speaks of purifying an effluent. Some explanation of this is necessary. The sewage of London is considerably more concentrated than the sewage of Columbus, owing to the fact that the water supply of London is only 30 gallons per capita per day, while that of Columbus is about 117 gallons per capita per day. All the sewage of London is purified by chemical precipitation, and it is the effluent from these tanks that is being used in the coke filters and which is proposed to further purify by 180 acres filters of like character.

Now the concentration of London sewage, that is, the amount of organic matter contained in the effluent from these chemical precipitation tanks is about two-fifths greater than is shown in an average sample of the sewage of Columbus, as it comes from the intercepting sewer. No exact way of comparing the suspended matters in Columbus sewage with the crude sewage used in English coke biological filters exists, owing to different methods of analysis, but upon the basis of the above comparison of organic matter it is not likely that the total solids in the Columbus sewage would exceed in amount that contained in the effluent from the London precipitation tanks.

The following table shows the reduction of suspended matter of the biological coke filters mentioned:

TABLE SHOWING REMOVAL OF SUSPENDED MATTER IN ENGLISH COKE BREEZE FILTERS

QUANTITIES EXPRESSED IN GRAINS PER GALLON.

Place.	Crude sewage.	After chemical precipitation or septic process.	After rough filtration.	Final effluent.
London 4 years (acre filter)	31	6.3	.....	Trace.
Sutton 6 months	60	.....	2.78	.075
Exeter 10 months	24.5	10.8	.....	Trace.

If further confirmation is needed of the attitude of some of the sanitary authorities upon coarse grain filters, it may be well to quote Mr. Bailey Denton, one of the most eminent of English sanitary engineers, whose extensive sewage disposal practice has made him an ardent advocate of land methods of sewage purification wherever it can be properly applied. In speaking of the prejudice against sewage farms in his recent book, Mr. Denton says :

"It was, it is to be presumed, as a result of this popular prejudice against sewage farms that in the session of 1893, the House of Commons in sanctioning provisional orders for the establishment of sewage farms, insisted that before the sewage shall be permitted to pass on the lands to be acquired, the faecal matter in suspension shall be removed by passing the sewage through a tank, or tanks, and treating the same by subsidence or filtration through coke or other suitable material. Such certainly were the words of the order with regard to the county borough of Northampton (population 70,000) in 1893, which the writer as consulting engineer, entrusted with the extension of the existing sewage farm, willingly complied with. As a result, a preliminary scheme of rough filtration (upward coke filtration) was designed, and having been in operation most successfully for more than a year, he proposes to recommend its adoption in all other works upon which he may be consulted in the future, whenever either the land is not of the most porous description, or in cases where the quantity of sewage discharged is greater than under ordinary circumstances the area of the land at command can purify. By this means, there is no doubt whatever that in such instances chemical treatment, with the heavy annual cost inseparable from its efficient management, can be avoided, as well as the initial outlay incurred by the construction of large precipitation tanks, which must prove altogether useless should the use of chemicals be for any reason set aside."

The experiments of the Massachusetts State Board of Health, at the Lawrence Experimental Station, are further confirmatory of the excellent results obtained from coarse grain filters. In the experiments made so far, purification is effected by mechanically straining the sewage through coke screens before applying it to the biological coke filters.

The rates through the biological coke filters are slow, with high efficiency, as compared with the London, Exeter

and Sutton filters, which are worked at high rates of flow and less efficiency.

Thus, in the reports of the Lawrence Experimental Station for 1896 (Mass. State Board of Health, page 501,) filter No. 65, filled with coke breeze, was found to purify at the rate of about 300,000 gallons per acre per day with a removal of from 96 to 99½ per cent. of impurities, (measured by albuminoid ammonia and bacteria,) and it is stated that :

"The filter has disposed of the applied sewage easily, and its effluent has been of satisfactory quality."

No mention is made in the report of trials with this filter at higher rates of flow and a smaller percentage of purification, which would be of great interest in view of the London, Exeter and Sutton results. Filter No. 81 is also a coarse grain filter, with cinders as a filtering medium, and operated by filling and emptying as before described. The sewage run into this filter was ordinary Lawrence sewage, strained through coke, but still about 25 per cent. more concentrated than Columbus sewage.

The report says :

"This filter received sewage at the rate of from 514,000 to 610,000 gallons per acre per day, with a purification of from 50 to 75½ per cent., the results showing less favorably for cinder than for coke."

Filter No. 22A of coke breeze five feet deep, was operated at a rate of 360,000 gallons per acre per day, with a purification of 65½ to 86 per cent.

This was with crude Lawrence sewage, fully twice as concentrated as Columbus sewage.

TABLE SHOWING RESULTS OF EXPERIMENTS WITH COARSE GRAIN FILTERS.

LAWRENCE EXPERIMENT STATION—COMPILED IN PERCENTAGES, 1896.

SEWAGE ABOUT 25% MORE CONCENTRATED THAN COLUMBUS SEWAGE.

Filter No. 65; Coke Breeze 5 ft. deep. Rate of flow 279,000 gallons per acre daily.

Entire Year of 1896.	Ammonia.		Nitrogen as		Oxygen Consumed.	Bacteria per cubic Centimeter.
	Free.	Albuminoid.	Nitrites.	Nitrates.		
Strained sewage....	4.07	0.41	.....	.....	2.12	1,500,000
Effluent.....	0 51	0.38	2.49	.024	0.12	11,127
Purification per cent	87½	90½	.....	.....	93	99½

SEWAGE ABOUT 25% MORE CONCENTRATED THAN COLUMBUS SEWAGE.

Filter No. 65; Coke Breeze 5 ft. deep. Rate of flow 300,000 gallons per acre daily.

Based on last 5 Months of 1896.	Ammonia.		Nitrogen as		Oxygen Consumed.	Bacteria per cubic Centimeter.
	Free.	Albuminoid.	Nitrites.	Nitrates.		
Strained sewage....	4.084	.440	.....	.....	2.21	1,605,800
Effluent.....	.266	.0366	.....	.....	0.15	6,552
Purification per cent	.....	96½	.....	.....	93	99.6

SEWAGE ABOUT 25% MORE CONCENTRATED THAN COLUMBUS SEWAGE.

Filter No. 81; Cinder 4.5 ft. deep. Rate of flow 562,100 gallons per acre daily.

Nov. and Dec. of 1896.	Ammonia.		Nitrogen as		Oxygen Consumed.	Bacteria per cubic Centimeter.
	Free.	Albuminoid.	Nitrites.	Nitrates.		
Strained sewage....	5.12	.545	.....	.....	2.92	2,476,500
Effluent..... ..	4.46	.27	.....	.....	1.04	606,400
Purification per cent	.....	50½	.....	.....	64½	75½

SEWAGE ABOUT 25% MORE CONCENTRATED THAN COLUMBUS SEWAGE.

Filter No. 22 A; Coke Breeze 5 ft. deep. Rate of flow 360,000 gallons per acre daily.

January and February 1896—Filter destroyed in March by Freshet.	Ammonia.		Nitrogen as		Oxygen Consumed.	Bacteria per cubic Centimeter.
	Free.	Albuminoid.	Nitrites.	Nitrates.		
Crude sewage.....	4.13	0.685	.....	.....	3.23	.....
Effluent.....	1.243	0.096	.....	.....	1.12	164,150
Purification per cent	70	86	.....	.....	65½	.....

With these data of coarse grain filters before us, it has been thought desirable to work out two projects for biological filters, preceded by mechanical screening and followed by further purification, either by intermittent filtration through land, or in artificial biological filters of finer grain. The first of these propositions is known as Project No. 6, now considered. In this project it is intended to pump the sewage through a cast iron main to the Miller and Schwenker farms, two miles distant, as outlined in Project No. 3. There it will pass into a screen house, where by widening the chanel of flow, the velocity will be reduced. At a slow rate it will pass through vertical screens, of an aperture as fine as will be found practicable. By this process the coarser articles and fibrous matter, which would otherwise clog the interstices of the filter, will be removed by hand and promptly burned in crematories. From the screen house the sewage will flow through a central distribution channel, from which it will be delivered to the coke breeze filters, which will be filled and emptied as before described. Eighteen acres of filter five feet in depth have been planned and estimated, which will give a rate of flow of 1,112,000 gallons for the maximum, and 883,000 gallons for the average flow per acre each 24 hours, inclusive of rest periods. In a three foot filter as operated at Crossness, and on the supposition that cubical contents and not superficial area are the controlling features of a coarse grain filter operated as is proposed, this would be equal to 30 acres and a rate of flow of 667,000 gallons maximum and 500,000 gallons average flow, this latter being one-half the rates fonnd practicable at Crossness.

After leaving the coke filters the sewage will pass upon the intermittent filtration beds, as outlined for the effluent in Project No. 3, and receive a further purification through sand and gravel at the rate of 270,000 gallons per acre per day, including rest periods bringing the final degree of purification fully up to 95 per cent.

This project has to contend with the same difficulties that embarrass Project No. 3 for this same location, namely, high cost of preparing the land for secondary filtratiou, insufficient area of the same for future extensions, and high lift at the pumping station. It has not made as favorable an impression on us as Project No. 7, for further artificial purification. (See Plate K for plan of Project No. 6.)

PROJECT NO. 7.

MECHANICAL SCREENING; DOUBLE COKE INTERMITTENT FILTRATION.

It was unforeseen that this project would compare favorably with other methods, until the great difficulty of finding a suitable quantity of land for even rapid filtration of the effluents from other processes began to engage our attention. It was then decided to estimate the cost of what might be termed double artificial intermittent filtration. The location for this project will be in the vicinity of the pumping station and the screen house will be placed so that the crematories can use the pumping station stack, the screen house being ventilated by the stack ventilator flue.

The first filtration will be through coke beds of the same capacity as those proposed in Project No. 6, namely, 18 acres in area, and at the rates there described. The elevation of these beds is to be such that the effluent from them may be made to pass out onto a second series of beds of equal area but finer grain, being in fact the screenings from the coarser beds as far as practicable, and containing a surface layer of coarse sand, very fine gravel, or coke dust, or a mixture of them, as may be found most economical.

The remarkable performance of coke filters at Sutton, England, would lead us to expect eminently satisfactory results from such an arrangement, if carefully studied. No success can be expected from haphazard design or thoughtless execution. The process is apparently highly successful at all places where a good degree of care and skill are put in charge, not alone on installation but in the practical working.

The estimated cost of this project seems to be satisfactory, and it is thought that careful study will reduce the amount of filtration bed estimated, rather than increase it, as rates of flow have been adopted much less than those in use elsewhere.

All the subject matter cited in Project No. 6, in favor of artificial coke filters, applies with the same force to this project.

Several reasons might be given why this project impresses us favorably :

1st. Its sufficiency seems to be well established, and to rest upon principles fully demonstrated in actual operation.

2nd. It seems to embody the best practice and thought among sanitary experts.

3rd. Its first cost and running expense compare with other projects very satisfactorily.

4th. It is capable of gradual development from a small beginning.

5th. It involves no uncertain business investment or large working force.

6th. It is simple.

7th. It is quickly installed.

8th. It may be made supplemental to chemical precipitation if desired.

9th. It can be most conveniently located so as to reduce pumping and operating expenses, and requires but comparatively little land. (See Plate L for Plan of Project No. 7.)

GENERAL CONCLUSIONS.

In working out the seven projects described, it has been the endeavor to bring them to a given standard of efficiency; each has been worked out with the same completeness of detail, so as to estimate it both in first cost and running expenses with reasonable accuracy. As far as possible, the same unit prices have been used in making up the estimates.

Other projects have suggested themselves from time to time, and have been worked out only so far as to prove their impracticability as compared with those presented. Some modifications of these projects included in the report have been estimated, but it has not been thought necessary to include such estimates herein.

With distinct predilection toward land methods of sewage purification and the early expectation that intermittent filtration would play some important part in any scheme that might be finally adopted, it was with surprise that it was found that no land method of disposal presented distinctly favorable features, and it was with further interest observed that artificial filtration became necessary to so many of the projects.

The following tables of comparative cost illustrate clearly the relative rank of the different projects, both on first cost, running expenses and capitalization. On the basis of efficiency, which is the first consideration to be thought of, we believe that the seven projects are nearly equal. Possibly the land methods are slightly higher in efficiency than the chemical or artificial filtration method, but the aim in design has been to have each project capable of purifying the sewage with a general efficiency of at least 95 per cent. of organic matter removed. On the score of efficiency, therefore, we feel that there is not much choice. Comparing the projects on the basis of economy, we find that the following table of comparative standing is helpful:

TABLE SHOWING COMPARISON OF COST BETWEEN THE VARIOUS PROJECTS CONSIDERED FOR SEWAGE PURIFICATION FOR THE CITY OF COLUMBUS, OHIO.

PART I. SHOWING FIRST COST AND CAPITALIZATION.

Method.	First Cost of Installation.	Relative Rank.	Cost of Pumping at 10 Cents.	Depreciation.	Interest at Four Per Cent.	Running Expenses.	Total Capitalization.	Relative Rank.
Project 1.— Broad Irrigation and Intermittent Filtration	$524,528	4	$9,450	$8,504	$20,981	$5,800	$1,642,903	4
Project 2.— Chemical Precipitation and Coke Filtration	342,244	1	5,400	5.703	13,689	17,500	1,399,544	1
Project 3.— Chemical Precipitation and Land Filtration	550,518	6	9,180	8,784	22,020	21,330	2,083,368	7
Project 4.— Ferozone Polarite System	487,000	2	4,050	8,270	19,480	15,000	1,657,000	5
Project 5 — Septic System	579,795	7	3,780	8,695	23,191	6,400	1,631,445	3
Project 6.— Coke Filtration & Land Filtration	542,396	5	9,180	7,863	21,695	6,390	1,670,596	6
Project 7.— Double Coke Filtration & Mechanical Straining	508,600	3	4,500	7,629	20,344	4,500	1,432,925	2

PART 2. SHOWING OPERATING EXPENSES.

Method.	Total Cost of Operation.	Relative Rank.	Cost per Capita.	Cost per Million Gallons.	Actual Running Expense, Including Pumping.	Relative Rank.	Cost per Capita.	Cost per Million Gallons.
			Cents.				Cents.	
Project 1	$44,735	4	39	$16 50	$15,250	3	13.3	$5 65
" 2	42,292	3	36¾	15 65	22,900	6	19.9	8 45
" 3	61,314	7	53¼	22 75	30,510	7	26.5	11 25
" 4	46,780	6	40¼	17 30	19,050	5	16.5	7 05
" 5	42,066	2	36½	15 60	10,180	2	8.9	3 78
" 6	45,128	5	39¼	16 70	15,570	4	13.5	5 77
" 7	36,973	1	32	13 65	9,000	1	7.8	3 32

TABLE SHOWING THE COMPARATIVE RANK OF DIFFERENT PROJECTS IN POINT OF ECONOMY.

No.	Method.	Rank on Total Capitalization at 4 per cent.	Rank on First Cost.	Rank on Total Running Expense including interest and Depreciation.	Rank on Actual Running Expense.
1	Broad irrigation combined with intermittent filtration.	4	4	4	3
2	Chemical precipitation combined with coke filtration..	1	1	3	6
3	Chemical precipitation combined with land intermittent filtration.....	7	6	7	7
4	The Ferozone Polarite process.....	5	2	6	5
5	The Septic system	3	7	2	2
6	Mechanical straining coke filtration, intermittent filtration on land.....	6	5	5	4
7	Mechanical straining, double coke filtration.....	2	3	1	1

In deciding upon relative merits, first consideration should be given to the column representing total capitalization, but the second column representing total outlay is by no means an unimportant consideration, while the comparison based on the cost of operation and actual running expense should receive some consideration in coming to a decision. We may therefore easily reject, on the score of economy, Projects No. 3 and 6 as being the two highest. Project No. 4 we do not further consider as being a proprietary process, its advantages finally depending upon the terms of a contract, the discussion of which we do not feel called upon to enter.

The **Septic System**, as we have before indicated, is of great interest and unquestioned merit, but we would not at this time feel warranted in recommending its use on so large a scale without great caution, and as it does not appear to be of such low cost as to warrant further consideration, we would set it aside for the purposes of this report.

By a process of exclusion we narrow down the choice to the following propositions, stated in economic order :

Project No.	Economic rank.	Method.	Capitalization.	Annual total operating expenses.	Operating expenses per capita per annum.
2	1	Chemical precititat'n with coke filtra'n.	$1,399,544	$42,292	36¾ cents
7	2	Double coke filtration....	1,432,925	36,675	32 cents
1	3	Broad irrigation.....	1,642,903	44,735	39 cents

It will be noticed that in capitalization the chemical process and the double coke filtration are very close together, and in this connection it is but fair to say that should allowance be made for the self-support of the sewage farm, that project would also rank closely with those above mentioned. Taken as a whole then, we do not think the economic comparison points out definitely any one of these three propositions, and selections should be made upon other considerations.

Among these considerations are simplicity of management, convenience of installation, and adaptability.

SIMPLICITY OF MANAGEMENT.

We would point out that simplicity in the operation of the plant is a most important feature. As we have already intimated, the conduct of a sewage farm is a large business, involving first-class management, strict economy, and great skill. Over 100 men and 60 horses will be needed. From $15,000 to $20,000 worth of produce must be sold each season, and considerable risk is involved in undertaking such a business. It has been suggested that the farm may be leased to advantage, but the chief end to be obtained, viz.: the proper purification of the sewage, is not generally so well accomplished under such circumstances as when the municipality undertakes the operation itself.

From this general objection the process of **chemical precipitation** is much more free. It is an operation involving about the same sort of management as a mill or machine shop, but no produce has to be sold. Chemicals have to be purchased and mixed and the process cared for. About 30 men will be employed about one-half of the year, and a good de-

gree of skill in the management has ample field for economies without undertaking large risks. The process is well known and well tried.

But if chemical precipitation has large advantages over sewage farming, the process of **mechanical screening** followed by **double coke filtration**, has equally large advantages over chemical precipitation. Here nothing has to be purchased; no renewals have to be made; about 10 men will be needed. These, under the direction of a competent chemist, have to operate the flow into the different beds, remove and burn the coarser matter from the screen house, and keep the plant as a whole in general repair. The advantage of this feature is marked.

CONVENIENCE OF INSTALLATION.

Another important consideration should be noticed in making a final selection. The installation of even a portion of the broad irrigation can not be made without first building the discharge main, buying the land, underdraining and improving it. To provide for the first 5,000,000 gallons of sewage at least one-half of the total expense would have to be incurred, or about $252,500, and the operating expenses would be large in proportion to the quantity purified.

The chemical precipitation method is, on the other hand, much more elastic and adaptable, and may be commenced upon a small scale and extended from season to season as finances will permit, or the quantity of sewage require. The cost of handling the first 5,000,000 gallons of sewage is estimated at $103,000, and the operating expenses would be almost directly proportional to the quantity of the sewag purified.

But if the chemical precipitation and coke filtration method presents superior adaptability over the sewage farm in this respect, the **double coke filtration** also excells the chemical precipitation method. There is no limit to the economy of the first installation, or the elasticity of its later expansion, save in the size of the individual filter beds. It is therefore entirely practicable to commence operations under this method with a double bed of two acres for the first installation, and add to this as rapidly as circumstances w il permit. The estimated cost of a preliminary installation of

this kind, capable of purifing from 500,000 to 1,000,000 gallons of sewage, and consisting of one double filter bed of two acres in area, screen chamber, channels, etc., is placed at $18,200 if located on land purchased for the pumping station.

The estimated cost of an installation, capable of purifying the first 5,000,000 gallons, will not exceed $114,000, including sufficient land for the full plant. Operating expenses will be proportional to the quantity of sewage purified.

ADAPTABILITY OF DESIGN.

One further consideration should be pointed out. The adoption of the double coke filtration in small preliminary units will allow the addition of chemical precipitation to it later if disposed, as all estimates on chemical processes have included intermittent filtration for the effluents, and a single filtration through coke is an essential feature of Project No. 2. It therefore can be considered that a preliminary installation of a small filtering area of coke is preliminary both to the completion of Project No. 2 for chemical precipitation, or Project No. 7 for double coke filtration; and inasmuch as these are the most economical projects in rank, an admirable latitude is given for development, as experience and further confidence seem to warrant.

A conservative course is desirable in installing any plant for the purification of the sewage of the city of Columbus. We would not advise, even if it were possible, that an entire plant capable of purifying the sewage of the city should be completed in one season. A judicious and early beginning should be made, upon a project which seems feasible, and as confidence is gained in its working by our citizens, its extension, based upon the experience acquired, should be followed up from year to year until the complete plant represents the success which is sure to crown all cautions, conservative but persistent effort to reach the end desired.

Estimates Upon Methods of Sewage Purification for Comparative Purposes.

In estimating the different projects, it is assumed that the pumping station is a part of the storm water system for the West Side, and it has not been included in the disposal works. The cost of the pumping has been included in the running expenses of each project.

PROJECT No. 1 — BROAD IRRIGATION WITH INTERMITTENT FILTRATION.

SITE IN HAMILTON TOWNSHIP.

First Cost.

Land	$158,812	
Levee	8,662	
Underdrains	66,178	
Distribution	20,220	
Filtration	24,673	
Stock and tools	25,280	
Force main	165,069	
Land east of canal	7,950	
Add 10%	47,684	
		$524,528

Running Expenses.

Labor and material	$25,000	
Interest	20,981	
Pumping	9,450	
Depreciation, etc	8,504	
Total expense	$63,935	
Estimated income	19,200	
Net expense	$44,735	
Capitalization at 4%		$1,118,375
Total capitalization		$1,642,903

PROJECT No. 2 — CHEMICAL PRECIPITATION WTIH COKE FILTRATION.

AT A SITE NEAR PUMPING STATION.

First Cost.		
Land	$20,000	
Buildings	16,500	
Machinery	39,750	
Channels, etc	29,603	
Filter beds	100,800	
Tanks	104,480	
Add 10%	31,113	
		$342,244
Running Expenses.		
Labor and material	$17,500	
Interest, 4%	13,689	
Pumping	5,400	
Depreciation	5,703	
	$42,292	
Capitalization at 4%		$1,057,300
Total capitalization		$1,399,300

PROJECT No. 3 — CHEMICAL PRECIPITATION WITH LAND FILTRATION.

ON MILLER AND SCHWENKER FARMS.

First Cost.		
Land	$71,575	
Grading	81,000	
Underdrains	60,086	
Carriers	22,237	
Force main	47,490	
Transmission	3,000	
Buildings	16,500	
Machinery	39,750	
Channels, gates, etc	29,603	
Tanks	104,480	
Extra land	24,750	
Add 10%	50,047	
		$550,518
Running Expenses.		
Labor and material	$21,330	
Interest, 4%	22,020	
Pumping	9,180	
Depreciation	8,784	
Annual operating expense	$61,314	
Capitalization at 4%		$1,532,850
Total capitalization		$2,083,368

F. H. Eno

PROJECT No. 4 — FEROZONE POLARITE PROCESS.

SITE NEAR PUMPING STATION.

First Cost.

Cost of plant as estimated by the American Sanitary Engineering Company....	$467,000	
Add for land on site near pumping station	20,000	
		$487,000

Running Expenses.

Labor and material as stated by the American Sanitary Engineering Company....	$15,000	
Interest, 4%	19,480	
Pumping	4,050	
Depreciation	8,270	
	$46,800	
Capitalization at 4%		$1,170,000
Total capitalization		$1,657,000

PROJECT No. 5—THE SEPTIC SYSTEM WITH COKE FILTRATION.

SITE NEAR PUMPING STATION.

First Cost.

Land	$20,000	
Grading	43,578	
Tanks	230,400	
Filters	151,200	
Underdrains	9,500	
Screen house	7,500	
Water supply	4,000	
Add 10%	43,617	
		$579,795

Running Expenses.

Labor and material	$6,400	
Interest, 4%	23,191	
Pumping	3,780	
Depreciation	8,695	
Annual operation	$42,066	
Capitalization at 4%		$1,051,650
Total capitalization		$1,631,445

PROJECT No. 6 — COKE FILTRATION FOLLOWED BY LAND FILTRATION.

SITE ON MILLER AND SCHWENKER FARMS.

First Cost.

Land	$71,575	
Grading	81,000	
Underdrains	60,086	
Carriers	22.237	
Force main	47,490	
Extra haul	40,000	
Filter beds	151,200	
Screen house	7,500	
Center carrier,	12,000	
Add 10%	49,308	
		$542,396

Running Expenses.

Labor and material	$6,390	
Interest	21,695	
Pumping	9.180	
Depreciation	7,863	
	$45,128	
Capitalization at 4 %		$1,128,200
Total capitalization		$1,670,596

PROJECT No. 7 — DOUBLE COKE FILTRATION.

SITE NEAR PUMPING STATION.

First Cost.

Land	$20,000	
Grading	14,400	
Filter beds	302,400	
Screen house	12,500	
Carriers	12,000	
Underdrains	9,500	
Add 10%	37,800	
		$508,600

Running Expenses.

Labor and material	$4,500	
Interest, 4%	20,344	
Pumping	4,500	
Depreciation	7,629	
	$36,973	
Capitalization at 4 %		$924,325
Total capitalization		$1,432,925

PART II.

The Storm Water Problem of that Portion of the City Lying West of the Scioto River.

THE FLOOD CONDITIONS.

The general description of the topographic feature of the city, in Part I. of this report, will enable those who have not given the local conditions close attention, to understand the difficulties which confront a considerable portion of the West Side in the disposal of its storm water.

With a naturally porous soil, and in ordinary stages of the river, with little or no trouble from storm water, this district of the city finds itself confronted almost annually with an inundation which submerges many paved streets, and floods some hundreds of cellars. This inundation is due largely to the fact that the usual high stages of the Scioto river in the wet season are considerably above the level of about one and one-half square miles of populated territory; and while levees extending along the entire river front usually prevent submergence, the ordinary flow of the sewers at such times is shut off by flood gates, and their flow accumulates until the high water of the river is sufficiently abated.

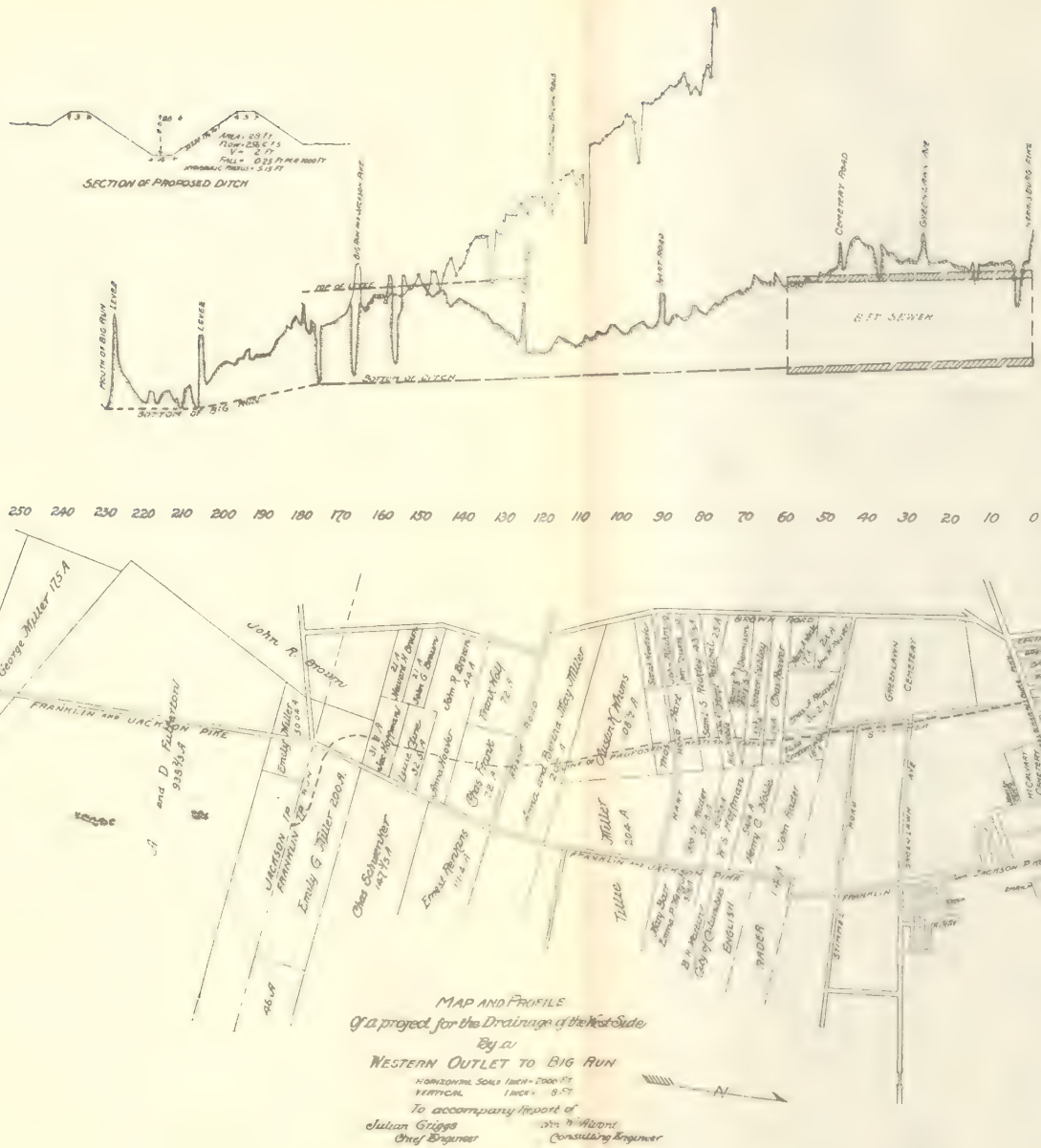
Where floods are of short duration and the river quickly subsides, no serious inconvenience results, but once or twice in each season it happens that the river does not recede promptly enough to prevent the collected sewage and rain-water behind the levees from rising to an inconvenient height and causing considerable annoyance. If at such times heavy rainfalls occur, further raising the impounded water level, much damage results and flood conditions prevail in certain low portions of the district. When the rapid growth of this section of the city in recent years is borne in mind, and the permanent character and high average value of the improvements is considered, it is not surprising that there is a general demand for a complete and thorough prevention of the evils which have been suffered.

THE FLOOD OF MARCH 23, 1898.

During this investigation there occurred a flood, memorable in the annals of the city, which afforded an object lesson not soon to be forgotten. To a river already at a high stage, and with the country tributary to it soaked with continued wet weather, there was added upon the water shed above Columbus a fall of from two and a quarter to three and a half inches of rain in forty-eight hours. The river was filled to overflowing, the entire valley both above and below the city was completely submerged, the levees in every direction were overtopped and broken. Notwithstanding the relief furnished by such natural reservoirs as the low lands behind the levees afforded, a stage of water two and three quarters feet higher than ever before recorded was reached, and new high water marks established in every direction. At the Asylum pumping station the flood level reached a height of 45.75 feet above city datum. At the city water works the engines of which were entirely submerged, the elevation of the flood was 41.80 feet. At Broad street bridge it rose to 38.95 feet; at a point above the State dam an elevation of 34.75 was established, being 13.09 feet above the crest of the dam. At the Stimmel road, with the valley flooded from bluff to bluff more than a mile in width, as far south as the eye could see, the water registersd 26.40 on the city gauge, a rise of nearly 19 feet above low water at this point. It is estimated from such data as could be observed that the river at its maximum stage passed not less than 75,000 cubic feet of water per second.

A considerable portion of the populated part of the west side of the city, probably not less 800 acres, was completely flooded, and the inflowing waters finding a short cut through the lowest portion, swept across this section with a rapid current, doing a large amount of damage both personally and upon the municipality at large.

As prompt and energetic steps have already been taken to avert a recurrence of such disaster, we do not feel it necessary to enter further into its discussion save to point out that the levee should be raised to such a height and the water way of the river so improved that no recurrence of this unfortunate condition of affairs can be possible,


SECTION OF PROPOSED DITCH
AREA = 28.11
FLOW = 258.6 CFS
V = 9.2 FT
FALL = 0.25 FT PER 100 FT
HYDRAULIC RADIUS = 2.13 FT
MOUTH OF BIG RUN LEVEE
LEVEE
BOTTOM OF BIG RUN
BIG RUN INTERSECTION AVE
SOUTH WESTERN OUTLET
CEMETERY ROAD
GREENLAWN AVE
8 FT. SEWER
250 240 230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
George Miller 175 A
John R. Brown
FRANKLIN AND JACKSON PIKE
Emily G. Miller 200 A
Chas Schmeiter 147.75 A
Ernest Rogers 11.4 A
Miller 200 A
Tillie
ENGLISH
PAGE
GREENLAWN CEMETERY
MAP AND PROFILE
Of a project for the Drainage of the West Side
By a
WESTERN OUTLET TO BIG RUN
HORIZONTAL SCALE 1 INCH = 2000 FT.
VERTICAL 1 INCH = 8 FT.
To accompany report of
Julian Griggs
Chief Engineer
Wm. H. Alvord
Consulting Engineer

RELIEF HERETOFORE ATTEMPTED.

The difficulties from back water during times of flood have not been ignored by the citizens of the West Side, and many projects have been suggested from time to time to obviate the difficulty. The more prominent of these projects have sought to take advantage of the natural fall of the Scioto river to obtain an outlet at some point well below the city, where a gravity flow could be maintained at all times. Such considerations doubtless largely influenced the designers of the Renick run and dry flow sewers, and are apparent in the very ingenious project for an outlet into Big run by a natural route west of the Jackson pike, of which we shall speak later.

There is no doubt that considerable advantage is gained by these means, but it is a somewhat deceptive one. In examining and comparing the various high water levels in the valley below the city with the level of those districts which it is designed to drain, a certain amount of fall is observed which seems to point to a successful outlet. Two things are often overlooked in such an investigation :

1st. That an efficient drainage system for the West Side should provide not alone for the prompt removal of the storm water from the surface of the streets, but also for the effectual drying out of the soil to a level of at least eight feet below the surface, so that suitable cellars can be excavated throughout the district, and *be maintained at all times free from dampness.*

To accomplish this result it is necessary that the water of the soil be lowered to a level of 16 feet above city datum all along the Harrisburg pike, making the drainage level eight feet below the lowest grade of the street. No extreme high water marks have been observed in the lower valley, within a reasonable distance, below 20 feet above city datum.

2d. In seeking for low outlet levels at increasingly greater distances, as in the present case, it must be borne in mind that the fall that any given channel must have for its full capacity is, roughly speaking, inversely proportioned to its size.

Large rivers do not require the same fall as small streams, to obtain their maximum delivery. Two artificial advantages

may in part offset this principle. Large bends in the greater streams may be cut off and distance thus gained, and the minor channel may be constructed of masonry so that frictional resistance is reduced to a minimum. In the problem before us, the material advantage to be gained by going even as far south as the Stimmel road has not resulted in a level of outlet sufficient to accomplish the drainage which is necessary, and it happens at the time when drainage is the most needed that the capacity of the outlet sewers are largely reduced or entirely cut off. The greatest advantage of an outlet so far south as the Stimmel road is to unite a pumping plant, if found to be necessary, with the pumping plant to raise the sewage of the entire city to the purification works.

A WESTERN OUTLET PROJECT.

A very interesting project has been suggested by the Director of Public Improvements, for an outlet through a channel running south along the east side of Greenlawn cemetery, and from thence directly south to Big Run at a point about a half mile above its junction with the Scioto river. The total distance a channel would have to be constructed in this location would be 22,000 feet, or about four and one-third miles, abost 6,000 feet of which should be of brick masonry, while the remainder might be open channel. Surveys have been made, map and profiles of which with the proposed depth of canal are shown. Some rock excavation would be met with. (See inset opposite page 64.)

The high water mark at the junction of the canal with Big run has been measured at 19 feet above city datum, but the recent flood of March 23 raised this to 20 feet above. A canal with a capacity equal to an ordinary rainfall upon the populated area at high water must have a large cross-section in order to take advantage of low rates of fall; and in order to discharge such a rainfall, a surface width of 28 feet, a center depth of 8 feet, and a fall of 3 feet to the 1,000 feet is necessary, or a total fall of 5.5 feet. Adding this fall to the usual high water mark of 19 feet at Big run, would still allow the flood water to rise to the height of 24.5 feet at the Harrisburg pike, or some 8.5 feet above the level to which it is proposed to drain, and also above the level of the paved streets in this and other localities. No adequate relief could be obtained from such a canal in time of combined rainfall

and high water, unless it be provided with a pumping station.

In ordinary weather it would doubtless prove efficient, but unless it was carefully maintained and kept entirely free from weeds and plants it would not have nearly the capacity stated.

THE PRESENT DRAINS AND SEWERS.

Several systems of sewers have been planned and partially carried out, for portions of the west side territory. The oldest system constructed, drains a considerable area in the eastern end of the district, by a main sewer four feet in diameter, which empties into the river at a point a little above Mound street. There are about 2¾ miles of brick and pipe combined sewers connected with this outlet. What is known as the Mound street system embraces nearly four miles of storm water sewers, and drains a territory a little more to the west than the older system, although not entirely distinct from it, and is intended to supplement portions of it. This system was designed exclusively for storm water, and empties into the Scioto river at Mound street bridge by a main circular drain of 6½ feet in diameter. Both of these systems are completely closed from the river at high water by sliding iron gates at the outlet, raised and lowered by hand.

The third system, designed for sewage proper of the West Side, in connection with the Mound street and Renick run storm water systems, is locally known as the "dry flow sewer," and has an outlet near the English farm, about three-fourths of a mile south of Greenlawn avenue, where it terminates in a circular well on the bank of the river; the level of the bottom of the sewer at this point is 1.35 feet below city datum, or about nine feet below low water in the Scioto river.

It has been the intention to pump the sewage at this point, both from the east side intercepting sewer and the west side main sanitary sewer, to a sewage farm. This so called "dry flow," or sanitary sewer, is four feet in diameter at its point of outlet, and there had been constructed up to the time work was stopped, about four miles of brick, main and branch sewers connected with it.

Great difficulty was experienced in construction, especially in building that portion below the level of the water of the subsoil, and when it becomes necessary to remove the bulk-

heads, greater difficulty still was found in pumping the necessary water out of the sewer, because of its defective condition. It is at present used as a storm water relief sewer, overflowing into the river at its southern end.

The Renick run sewer system was designed exclusively for a storm water system, and was built at the same time as the Mound street storm water system. It drains that portion of the territory lying nearest to the rising ground on the west. Its outlet is situated a distance of about one and one-half miles south of the city limits, in a little run from which it takes its name, and which finds its way into the Scioto river through flap gates in the levee a short distance below the English farm. This main sewer extends through Central avenue to the north portion of the district, a total distance of nearly three miles. Its diameter at its outlet is 6½ feet, and is reduced at its upper terminus to two feet.

Notwithstanding the fact that it was designed for storm water only, about two miles of branch sewers, collecting both storm water and house wastes, have been connected with it at its upper end. This main sewer appears to be in good condition, and drains a large amount of surface water from the higher lands. It could have been profitably made larger and deeper, especially at its upper end.

The Renick run sewer, the Mound street storm water system and dry flow or sanitary sewer, have cost the city up to the present time about $322.428, or about $28,500 per mile. The cost of the older system is unknown.

So far as can be observed the sewers designed for the removal of the storm water can be made to serve that purpose, as originally intended. If they had been planned somewhat deeper, and in connection with pumps for high stages of the river, certain sections would have been better drained than at present. Nevertheless, inexpensive modifications can be made in their outlets by which they can be made to serve their original purpose as they now exist.

THE QUANTITY OF RAINFALL TO BE PROVIDED FOR.

The quantity of rainfall is one of the most important factors in determining the proportions of sewers ; it is, however, important to know its rate of intensity, the character of the soil, and the proportion of paved streets and roofs upon

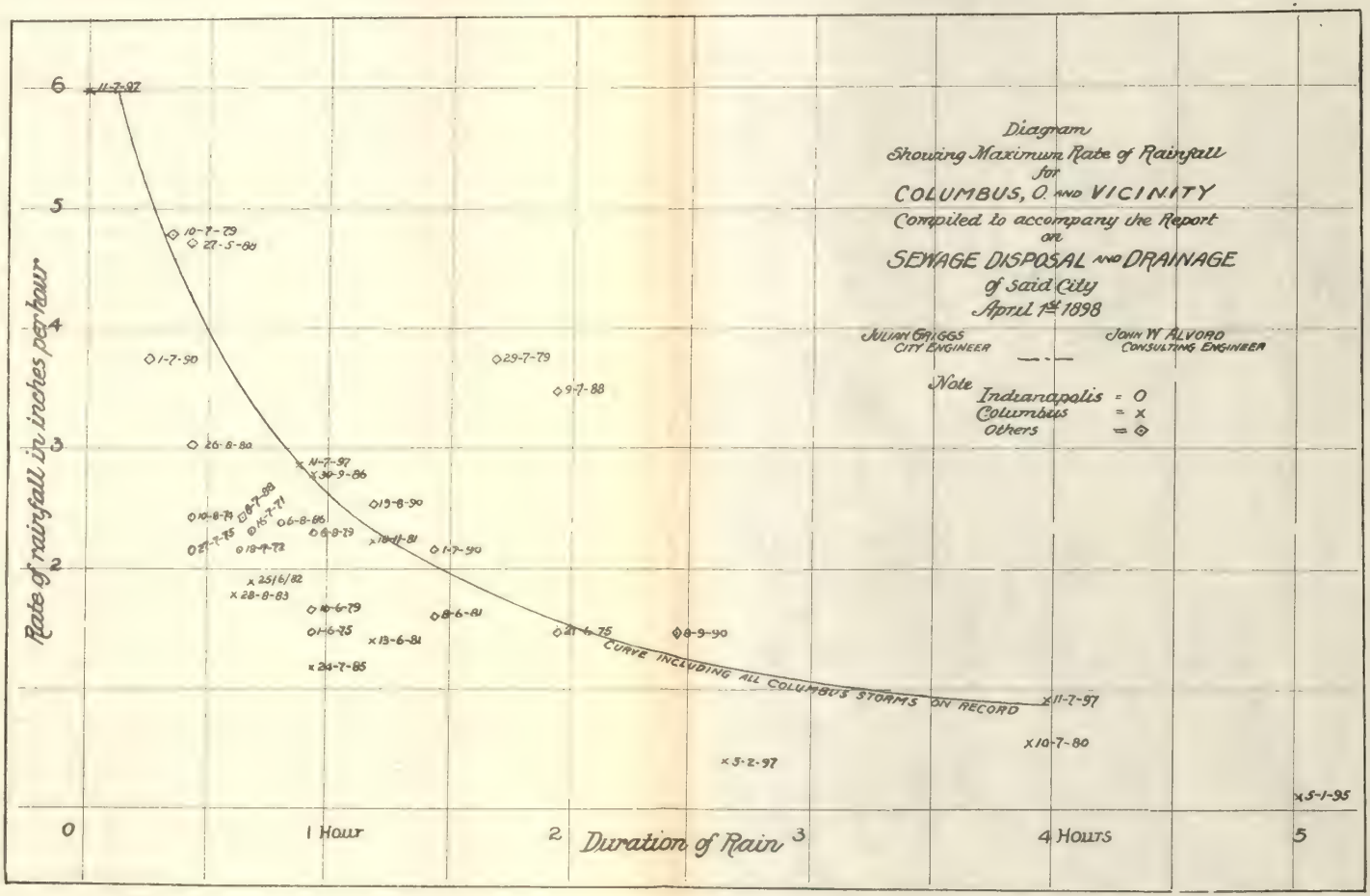


Diagram
Showing Maximum Rate of Rainfall
for
COLUMBUS, O. AND VICINITY
Compiled to accompany the Report
on
SEWAGE DISPOSAL AND DRAINAGE
of said City
April 1st 1898
JULIAN GRIGGS
CITY ENGINEER
JOHN W. ALVORD
CONSULTING ENGINEER
Note
Indianapolis = O
Columbus = X
Others = ◇
Rate of rainfall in inches per hour
Duration of Rain
1 Hour
4 Hours
CURVE INCLUDING ALL COLUMBUS STORMS ON RECORD
0
2
3
5
6
11-7-97
10-7-79
27-5-88
1-7-90
29-7-79
9-7-88
26-8-80
14-7-97
30-9-86
10-8-79
8-7-88
15-7-71
6-8-86
6-8-79
19-8-90
27-7-75
18-7-72
18-11-81
1-7-90
25/6/82
28-8-83
10-6-79
8-6-81
11-6-75
13-6-81
21-6-75
8-9-90
24-7-85
11-7-97
10-7-80
3-2-97
5-1-95

which it falls. The amount of water which will find its way to the sewers within a given time for these different factors varies greatly. In order to ascertain the greatest rate and intensity for which it is proper to provide in Columbus a compilation of all the more severe storms in this city and vicinity has been made, and is here presented. (See Inset op. page 68.)

It is interesting to observe from this table that the storms of greatest intensity all fell in the summer months when the dryness of the season best fitted the ground to receive and absorb them. This is a point of considerable weight in designing drainage of porous soil, and for suburban districts.

We conclude from the diagram that for a thoroughly paved and roofed area, with steep grades, so that the water quickly reaches the sewers, such for instance as the central district of Columbus on the east side, we would provide for the prompt removal of 2¾ inches of rainfall per hour, and from data afforded by several sewers in this district which were overfilled during storms of known intensity, we would suggest that the rule known as the modified Burkli-Ziegler formula seems to correspond best with actual conditions. This formula is as follows:

$$Q = c.\ r.\ \sqrt[5]{A.^4 S.}$$

in which

Q = The quantity of water discharged in cubic feet per second.
r = The rainfall in this case of 2.75 inches per hour.
c = A co-efficient of surface conditions varying as follows:
0.75 for well built up and paved surfaces.
0.62 for average city areas.
0.45 for suburban territory.
0.31 for rural districts.
A = The area in acres of the territory drained.
S = The average fall in feet per 1000 of the surface of the ground over which the storm water would pass.

The conditions which govern the central district of the city, and which bring the storm water to the sewers so rapidly, would not properly be applied to outlying territory, like the West Side, possessed of porous soil, largely of a residential character, and with a fair proportion of the area likely to be vacant for years to come. For this reason modifications in such a rule as have been given are found by experience to be quite proper. These modifications must always be a matter of judgment, based upon experience in works of this character. In order to show how widely the proportions of sewer may thus vary in a given locality, the following table is inserted of representative Chicago sewers, all of which for many years have been found capable of doing the work for which they were planned:

TABLE SHOWING CAPACITIES OF CHICAGO MAIN SEWERS,

TO ACCOMPANY REPORT OF JULIAN GRIGGS, CHIEF ENGINEER, AND JOHN W. ALVORD, CONSULTING ENGINEER.

Names.	Area in acres.	Present population.	Present population per acre.	Diameter in feet.	Grade one in.	Length in feet.	* Velocity of flow running full.	*Cubic feet per minute.				Capacity for storm water in inches per day.	Capacity for storm water in inches per hour.
								Sewer running full.	† Max. rate of flow of sewage.	Capacity for storm water.	Capacity for storm water per acre.		
Armitage avenue	2,905	58,500	20	9	2,500	6,050	4.00	15.300	2.421	12,879	4,433	1.77	.0737
" "	1,750	30,000	17	8	2,500	5,300	3.70	11,100	1,458	9,642	5,509	2.20	.0916
N. Clark street	370	32,500	88	6	2,500	3,200	3 05	5,220	451	4.769	12.890	5.12	.2130
Rush street	290	24,500	85	5	2.500	2,740	2.70	3,180	340	2,840	9,791	3.91	.1630
22d street, E. of State	710	41,500	59	6	2,500	1,500	3.05	5,220	592	4,880	6,873	2.75	.1150
35th " " "	800	47,000	59	6	2,500	1,200	3.05	5,220	667	4,5 3	5,691	2.28	.0950
41st " " "	425	15,000	35	4	2,500	4,200	2.35	1,740	354	1,386	3,261	1.30	.0542
45th " " "	545	15,000	28	4	2 500	5,050	2.35	1,740	4:4	1,286	2,359	0.944	.0393
51st " " "	910	10,500	12	5	1,000	840	4.25	5,040	758	4,282	4,705	1.88	.0784
56th " " "	1,490	18,500	12	4½	2,000	5,530	2.80	2.640	1,242	1,398	938	0.38	.0158
70th " " "	1,210	6,600	5	6½	2,500	3,900	3 20	6.360	1,008	5,352	4,423	1.77	.0737
73d " " "	1,125	6,500	6	6	2.000	4.570	3.40	5,760	938	4,822	4,286	1.71	.0712
W. Fulton street	310	25,000	81	5	2.500	2.250	2.70	3,180	347	2,833	9,486	3 63	.151
W. Randolph street	275	21,500	78	5	2,000	3,805	3.00	3.540	299	3,241	11,790	4.67	.195
W. Madison street	265	22,500	85	5	2,000	3,325	3.00	3,540	313	3,227	12,180	4.83	.201
W. Adams street	290	23,000	79	5	2,000	2,400	3.00	3,540	319	3.221	11,110	4.41	.184
W. Van Buren street	295	20.500	70	5	2,000	2,530	3.00	3,540	285	3,25·	11,030	4.38	.183
W. Harrison street	265	16,500	62	5	2,000	2,920	3.00	3,540	229	3.311	12,490	4.96	.207
W. 43d avenue	2,915	12,500	5	9	2,500	6,275	4.00	15,300	2,428	12,872	4,416	1.77	.0737

* Capacities and velocities computed from Kutter's Formula, using n = .013 and s = .001.

† Maximum flow of sewage is computed, assuming a flow of 20 cubic feet per day per person, and a population of 60 per acre, except where present population exceeds that, in which case present population is used.

These sewers drain all classes of territory—from that in a thickly built up portion of the city, where a capacity of 5.12 inches per day is necessary—to a sewer in the suburban territory, with a capacity of but 0.38 inches per day, and draining a thinly built section, which includes a large park. This table is not inserted for the purpose of drawing comparisons between Chicago and Columbus sewers, for drainage conditions are quite different in the two cities, in some respects radically so; but it is considered of interest as illustrating the modifications that may properly exist in the same city between the different portions of its area. Looking at the probable future growth of the west side district, the porosity of its soil and its residential character, we conclude that with rainfalls of 2¾ inches per hour, only about one half of this amount will reach the sewers directly, the remainder being drained away in the course of a few days following the storm by percolation through the soil to the sewers. In the rule before mentioned, therefore, we could substitute a value for "r" of 1½ inches of rainfall and make "c" equal to 0.62 as corresponding more nearly to the conditions as they will exist in this section. Estimating the capacities of the storm sewers already built on this formula, we find that most of them are of nearly proper size to remove the water of storms promptly if provided with suitable outlet. The Renick run sewer seems to be somewhat below the capacity which will be necessary, and will doubtless have to be supplemented in course of time. Some small extensions will also be necessary to the existing system.

THE "DRY FLOW" SEWER.

Much study has been given to the question how best to utilize the so called "dry flow sewer." Originally designed to collect household waste only, through radical defects in both design and construction, it does not seem fitted for this purpose. Our reasons for this conclusion are as follows:

1st. Having an outlet nearly nine feet below low water, it would be necessary to pump its flow throughout the entire year. Studies of the topography and stages of the river have shown us that it is possible to locate and construct an efficient sanitary sewer with an outlet at the Stimmel road, of sufficient elevation so that a considerable portion of the year pumping will not have to be resorted to, and during that

season, when it is necessary to pump this flow, the lift will not be so great by 9½ feet, an important item of expense.

2d. The construction of this sewer has been attended by so many difficulties, owing to its depth, that were it attempted to carry the sewage in it, a large unnecessary quantity of ground water would find its way through the defective masonry and have to be pumped. This would not only increase the cost of pumping but also the cost of purification works. It is suggested that the sewage might be passed through this sewer under pressure, by causing the level of the flow at the outlet to be lowered sufficiently to cause the proper discharge to take place. This indeed would be a happy solution to the problem if clean water alone were to be conveyed, but it must at once be objected to with sewage, on the ground that the decreased velocity, due to the large section, would cause deposits and allow decomposition to occur within the sewer, a condition which would be prohibitive.

3d. While the lower portions of the main sewer are ample in size and more than ample in grade, the upper branches as far as built appear to be deficient in the depth necessary to properly drain portions of the district. Studies have been made to see if it were not possible to utilize the sewer by building within it another water tight sewer which would answer the requirements before mentioned, and be more exactly proportioned to its work. This, however, would not obviate two of the principal objections we have urged. After very thorough consideration of this problem, we have decided to recommend that this sewer be utilized for an additional storm water sewer, its location and depth answering admirably for this purpose, and we believe it will prove to be more valuable to the city if used in this way than could be possible otherwise. With a minimum amount of suspended matter the sewer could be allowed to flow full and empty at any desired level, at low velocities, without fear of serious sedimentation in the sewer itself.

Its depth in the settled portions of the district is a great advantage, in that the ground water can be lowered in the soil to a desirable degree, and infiltration into a new sanitary system, if built as recommended herein, reduced to a minimum. The location of these sewers is such as to happily

coincide with our general plan for the storm water drainage of the West Side.

THE PROPOSED PUMPING PLANT.

Careful reflection upon the main facts of the storm water problem as we have presented them, can not fail to convince all those who are interested in the question, that the only practical way to thoroughly drain the lower portions of the West Side in the flood season of the year, will be by establishing a pumping plant. Our convictions on this subject are further confirmed, when it is found that in solving the problem of the final disposal of the sewage, it will be necessary to provide for pumping, no matter what project may be adopted. So long as the sewage can empty into the Scioto river and be properly diluted there, it will flow by gravity from the East Side intercepting sewer even at high stages of the river, without inflicting damage by backwater; but so soon as any project for purification or sewage farming is attempted, the sewage must be lifted from 13 to 35 feet in height, depending upon the project selected. This requirement will involve a capacity in machinery sufficient to raise 20,000,000 gallons of sewage in twenty-four hours in the summer. In the flood season the sewage pumping station would be idle, but if we connect it with the West Side storm water drainage, it will be possible during flood times, when it is not necessary to pump sewage, to devote its full capacity to the storm water drainage of the West Side, thus performing a double purpose at different seasons of the year.

QUANTITY TO BE PUMPED.

In installing a pumping plant for the removal of the storm water and sewage of the West Side in time of flood, it is only necessary to provide machinery for the actual quantity of the flow which will reach the pumps at the present time from the district in question. The building should be so planned that additions can be made to the machinery as the quantity of flow increases. The porous nature of the soil of this district, consisting as it does in many parts of beds of coarse boulder and gravel, allows us to estimate that if once the water in the soil is lowered to a standard level sufficient for cellar drainage, rainfalls will not be promptly delivered to the pumping station, but a large proportion will be held a certain length

of time in the soil before reaching the sewers. This feature has an important bearing upon the capacity of machinery required, for while the largest portion of water from any given storm may eventually reach the pumps in due course of time, yet if it is spread over a number of days, it is a much less formidable quantity to care for, and does not require excessive capacity of machinery, which would be idle at all except rare occasions. This principle applies to all porous soil drainage. The actual number of days in which pumping will be resorted to is small per annum, being confined to periods of high water in the river, the pumps being devoted at such times to keeping the level of the ground water down to the prescribed elevation, so that accumlation of flow in the drains will be prevented and a sudden storm will find ample storage capacity in the soil for its reception.

There are 1350 acres tributary to the so called "dry flow" and the Renick run sewers, which cover the area within the city limits needing relief. We have estimated that an installation of machinery capable of removing one inch in depth over this area in each twenty-four hours will be sufficient for a considerably greater flow than will have to be removed for some years to come.

Interesting data upon this point are afforded by four similar pumping districts in the city of Chicago. These districts with one exception are adjacent to Jackson park, formerly the World's Fair site, and are too low to be drained by gravity. The soil is porous in the first three districts, but it is of impervious clay in the fourth shown in the table.

The amounts pumped are taken directly from the records of the different stations, and show that in no case during maximum storms which have prevailed, has the amount pumped equalled one inch in depth over the entire area. The Woodlawn district is well built up and the streets are all paved and sewered, many of the more permanent World's Fair hotels occupying this locality being now turned into immense flat buildings; yet the maximum amount pumped in any one day from the sewers for the past ten years was but $\frac{1}{3}$ of an inch in depth in 24 hours for the area drained. The result is undoubtedly due to the porous nature of the soil.

TABLE SHOWING DATA OF CHICAGO SEWAGE PUMPING DISTRICTS, THEIR PHYSICAL CHARACTERISTICS AND DISCHARGE.

Especially Compiled for Report of Julian Griggs, Chief Engineer; Jno. W. Alvord, Consulting Engineer.

Name of District.	In Operation Since—	Area of District, Acres.	Size of Main Sewer—Feet.	Miles of Sewers in Dist.	Proportion Sewered.	Pavements.	Population.	Character of Subsoil.	Maximum Quantity Pumped in 24 Hours—Gallons.	Equival'nt Depth Over Whole Area in Inches.	Normal Quantity Pumped in 24 Hrs. Gallons.	Equival'nt Depth over Whole Area in Inches.
Woodlawn avenue..	1888	600	4	17.00	All sewered.	All..	25,000	Sand..	13,500,000	0.828	3,600,000	0.225
Seventieth street...	1892	1320	6½	38.50	All sewered.	Largely..	20,000	" ..	7,275,000	0.220	2,944,000	0.082
Seventy-third st ...	1891	1140	6	36.00	⅔ sewered..	Not much.	15,000	" ..	11,000,000	0.342	2,750,000	0.088
Indiana avenue....	1896	1108	3½	25.25	⅕ sewered ...	None.....	8,000	Clay ..	9,166,000	0.320	1,250,000	0.041

For the West Side of Columbus, one inch in depth over 1350 acres will amount to 56.25 cubic feet per second, or nearly 36,500,000 gallons in twenty-four hours. To this amount must be added the sewage flow of the West Side, which has been previously estimated for the first few years at not to exceed 2,400,000 gallons per day, and which must be pumped into the Scioto river at its high stages in the same manner as the storm water and at the same time. The total amount will, therefore, reach 38,900,000 gallons in 24 hours, or in round numbers 40,000,000 gallons.

PERCOLATION FROM THE SCIOTO.

It may be objected that in order to draw down the level of the ground water in the territory to be drained, it will be necessary to pump large quantities of percolating water from the Scioto river, especially at high stages of water. Our studies of this question convince us that this would not be the case, and it will not be amiss to present at this point our reasons therefor.

A silt bearing river like the Scioto annually brings down many tons of fine suspended matter, which when deposited upon its sides and bottom quickly forms an almost impervious coating. At high stages of the river the pressure of the water from the river side tends to firmly press this coating against the sides and bottom and prevent any outward percolation or flow into the surrounding soil. So soon as normal or low stages of the river obtain and the water of the surrounding soil becomes higher than the level of the water in the river, the pressure of the soil water easily detaches this film or skin, and finds its way into the river. No one who has lived near such a river as the Scioto and has been at all observant of its physical characteristics, can have failed to be impressed by this feature. Many thousand acres in the Scioto valley are protected by levees and remain comparatively dry for many days during flood stages, even when the river rises eight to ten feet high above the bottom lands. When the flood waters recede, it is noticeable how quickly such water as may have collected in the adjacent bottoms from rains or natural drainage of higher lands will disappear through the soil into the river.

For this reason we believe that not only can the level of

water in the soil of the bottom lands of the West Side be lowered sufficiently to allow the construction of cellars throughout the district, but we are convinced that natural causes will assist in preventing this degree of drainage from being burdened by percolation from the Scioto river. The level of the ground water along the northern edge of the district will not be reduced lower at any point than the low water level of the river, and while such drainage may materially protect the water supply intake from possible contamination, it will not reduce the quantity now being supplied to the intake at that point.

OTHER CONSIDERATIONS AS TO PUMPING.

It has been objected that to depend upon pumps for protection from backwater is in a measure open to possibilities of accidental derangement of the machinery at critical periods. This objection is a fair one and is entitled to consideration. We think it can be satisfactorily answered.

1st. The design and conduct of direct pressure water works in hundreds of cities throughout the country show that in installations such as we propose, this difficulty is at least uncommon. A well designed and managed pumping station should have the total capacity of its machinery divided into a sufficient number of units, and should be provided with reserve capacity, so that the derangement of any single machine will not involve the entire plant or prevent its effectiveness. With competent superintendence machinery should be at all times fully inspected and kept in repair, and anything short of this is negligence which should not be permitted. These remarks apply to all machinery in daily use where absolute dependence is necessary.

2nd. The ground water drainage of the West Side is not a case where a complete breakdown of the pumping station for a few hours or even a day can be vital. If the pumping station is effectually operated, the water in the soil will be lowered several feet and kept so lowered all of the time, so that the soil forms a vast reservoir, capable of holding the water from a number of storms before annoyance is felt. It is quite true that the rnn-off from the paved streets and roofs reaching the sewers directly, would flow to the out let, and were the pumping station not in operation for several days at times

of high water, it could accumulate upon the lower grounds near the levee on the English farm, but this is a much less serious contingency than is usually certain to be faced at the present time, and with the present arrangements.

If we allow that at time of high water the pumping station be suddenly deranged and that simultaneously a severe storm of one inch of rainfall on the district (an ordinary rain seldom exceeds one-fourth of an inch in depth), the total quantity thus precipitated over the 1,350 acres would be 4,900,500 cubic feet of water. If the ground water of the districts were ordinarily kept down to the level we have suggested, it is fair to assume in the present condition of the territory that fully three-quarters of this amount would be absorbed by the soil, leaving the remainder, or 1,225,000 cubic feet from the roofs and pavements to be carried into the drains. Now the drains themselves have a storage capacity of about 750,000 cubic feet, leaving 475,000 cubic feet to overflow near the outlet on the English farm, a quantity which would cover a little over five acres two feet deep. Even if it were found that the soil of the district did not take up one-half the rain-fall, the surplus at the outlet would cover but 20 acres two feet deep.

It is quite evident from these figures that if the district is kept dry a temporary derangement of the pumps will not be productive of serious inconvenience, but with reasonable attention it is not at all likely that serious stoppage can result. The machinery we have proposed to use is simple in construction and is not likely to get out of order. The number of pumping engines have been so fixed and their general arrangement is such that if one is out of use, the remainder would not be thereby incapacitated. Every precaution has been taken in the design of the station to provide against interruption of the plant by floods.

Of course no pumping station can be expected to deal with the waters of a flood such as occurred in March last, and it is important to provide against the recurrence of such a disaster by the raising of the levees and the improvement of the river bed. With these precautions we believe the inconvenience caused by the annual difficulty from back water can be entirely eliminated. Finally, we know of no other method by which this object, the drainage of the West Side, can be satisfactorily accomplished at all seasons of the year save by

some form of pumping arrangement in times of high water similar to that we have here proposed.

DETAILS OF THE STORM WATER DRAINAGE.

The pumping station is best located on the east bank of the Scioto river a little south of the Stimmel road, or about opposite the Emerich stove foundry. This site can be made accessible from the Hocking Valley Railroad by a switch track, by means of which the coal can be delivered at the boiler room. The expense of the connections to the storm water outlets and sanitary sewer on the west side of the river require that the building be placed as near the river as possible, otherwise a location more easterly and nearer the railroad would be selected. A four foot brick sewer about 1000 feet long will bring the sewage from the East Side intercepting sewer at the most favorable point in its grade to the suction pit of the pumps. Suitable controlling gates are arranged in the connection to regulate the quantity admitted to the pump pit, or exclude it altogether. The station will be connected across the river to a point back of the outlet of the main West Side storm water drain by two thirty-six inch cast iron pipes, laid under the bed of the river. This connection, if made in summer when the river is low, will not be unduly expensive.

The outlet of the West Side storm water drain will terminate in a chamber containing automatic flood gates, which will exclude the high water of the river from the drain, similarly to those now in use. The diameter of the main storm water drain will be nine feet, extending from the river on the Stimmel road, west to the Renick run sewer, with which it will connect, and the flow of which it will divert directly to the river in time of low water, and to the pumping station in time of flood. The river crossing pipe will also connect directly with the present so called "dry flow" sewer in the Stimmel road, and will be furnished with valves so that the entire capacity of the pumping station may be used on either the "dry flow" or Renick run sewer, or may be differentiated as may be found necessary.

Space for additional cast iron pipe, to be laid across the river in the future when necessary, has been planned. The present installation is fully equal to the capacity of the

pumps, but the storm water drain in Stimmel road has a capacity greater than is at present required, and is designed with reference to future demands. It may be extended north to supplement the Renick run storm water district. The combined capacity of this nine foot storm water drain and the so called "dry flow" sewer are, when properly extended and connected, together fully equal to the removal of 1½ inches of rainfall per hour over the 1350 acres to be drained, without being overcrowded.

At the present time 3700 feet of this drain only will be needed to connect with the Renick run sewer.

The outlet of the present dry flow sewer near the English farm should be improved by the introduction of large automatic valves placed so as to permit the sewer to drain by gravity lower than the present temporary outlet will permit. The outlet well at this point should be permanently covered. There should also be provided an automatic valve chamber in this sewer in the Stimmel road, immediately south of the connection to the pumping station, to prevent the water of the soil from the southern or outlet end, from engaging the capacity of the pumps in times of high water to the exclusion of more important drainage from the districts to the north. The construction of this chamber had best be deferred until the pumping station is in operation, as it will be difficult otherwise to build.

The present mouth of the Renick run sewer should be provided with an automatic flood gate, to guard against the possibility of accident to the levees south of the proposed Greenlawn avenue levee allowing the pumping station to be flooded. The man-holes on all drains in this district should be provided with tight covers kept two feet below the surface, for the same reason.

The outlet of the east side intercepting sewer, which is now an open man-hole, should be opened and a suitable bulkhead built.

The pumping station will also be connected with the outlet of the main sanitary sewer of the West Side, at Stimmel road, by a 20 inch cast iron pipe laid beneath the river and connected back of automatic flood gates. Provision is made for laying additional pipe in the future.

An intercepting or overflowing sewer should be laid in

Main street, between Gift and McDowell streets, of three and a half feet in diameter. This intercepting sewer should be so arranged that the overflow from the old main sewer in McDowell street, should run into the new three foot sewer in McDowell street, connecting with the Mound street storm water system, and a connection should then be made between this latter sewer and the 2 x 3 foot sewer in Gift street, directly west. This interception must be so arranged that overflow shall not take place in either case until the sewers are about two-thirds full, in order that the Gift street sewer may not be compelled to carry water to the low outlet, which would flow by gravity through the Mound street outlet.

At the interception of the Mound street sewer and the so called "dry flow" sewer on the Harrisburgh pike, an intercepting chamber should be built which will permit the water from the Mound street sewer to overflow into the lower sewer as soon as high water compels the closing of the Mound street outlet. The overflow should not take place until the Mound street sewer is about two-thirds full. Automatic flood gates can be put in the Mound street outlet chamber if desired, which would obviate the operation of these gates by hand, and the consequent close attention they now require in the season of high water. The present gates could be left as they now are for emergency purposes.

Some extensions of the present storm water system might be made, such as extending Scott street drain west, and connecting the Renick run sewer with the Mound street system on the Harrisburg pike; but generally speaking, the district east of Central avenue will be pretty well provided with storm water drainage, especially the eastern end.

With the interceptors and improvements above mentioned, plans for which accompany this report, (see plates Nos. 1 to 6 inclusive in back,) the district will have outlets in Mound street, Stimmel road, and at the English farm by the so called "dry flow" sewer. When high water closes the automatic outlets into the river the intercepting chambers will connect the entire drainage to the pumping station by way of the Renick run and proposed Stimmel road main drains, and the "dry flow" sewer. At the pumping station the flow will be lifted into the river until the high

water abates and allows the automatic gates to open and the system to resume its normal condition again.

DETAILS OF THE PUMPING MACHINERY.

The pumping station will be a brick building, 100 feet long by 36 feet wide. It will contain engine and boiler rooms. There will be four pumps, all of the centrifugal type; two of which will be capable of raising 5,000,000 gallons each 24 hours, and two others capable of raising 15,000,000 gallons each 24 hours. As the quantity to be pumped is variable, this arrangement of units will permit the greatest latitude in suiting economical operation to the work in hand.

The pumps should be driven by vertical compound condensing engines, with variable cut-off. The lift of the pumps will range from 2 to 20 feet, and the quantity from 3,000,000 to 40,000,000 gallons per 24 hours. The two larger engines, when pumping their rated capacity 20 feet high, should be capable of developing a duty of 60,000,000 pounds of water raised one foot for each 1,000 pounds of water evaporated in the boilers, and with not more than 180 revolutions of the engine per minute, on a pressure of 100 pounds of steam. The two smaller pumps on the same lift and at their rated capacity, should be capable of developing a duty of 45,000,000 pounds, under the same conditions and with not more than 300 revolutions of the engine.

The boiler room should contain four boilers of sufficient capacity so that when one is out of service the other three will be fully capable of supplying the necessary steam for the maximum work which the pumps are expected to perform, together with the feed and condenser pumps and pump primers. A suitable switch track should be built and connected direct with the Hocking Valley railroad, by which coal cars can be unloaded directly into the boiler room.

The suction chamber will be provided with a screen by which the coarser suspended matters in the sewage may be removed while the plant is pumping sewage. The two larger engines and pumps will have their suction pipes so arranged that they may be directly connected to the 36-inch river crossing pipe by means of the valves before mentioned. The discharge main will be 42 inches in diameter, and will lead directly to the river, terminating in a suitable bulkhead. Dur-

ing the summer, when sewage is being pumped to the purification plant, this discharge will be closed by a valve, and a branch main will lead to the purification works.

The boiler house and engine room are both planned so that additions can be readily made to the plant.

The cost of pumping the sewage in the dry season of the year has been estimated and charged against the sewage purification projects. The cost of the construction of the pumping plant itself is, however, considered a part of the storm water drainage, for the purposes of this report. It will be exceedingly difficult to properly estimate the amount and cost of pumping the storm water, due to yearly variations in rainfall. Rough estimates show that the running expenses during the wet season will add $6,000 per annum to the cost of pumping the sewage, which on the recommended Project No. 7 is found to be $4,500, making a total per annum of $10,500. In wet years this amount will be increased. (See plate M for plan of Pumping Plant.)

THE DRAINAGE OF THE HIGH LANDS OF THE WEST SIDE.

So far we have considered the storm water drainage of the bottom lands alone; this is really the serious part of the problem. Immediately west of this area, but partially included in it, lies the ground of the Columbus State Hospital and the Institution for Feeble Minded Youth, covering about 500 acres of land, which will, in all probability, never be built upon. West of these tracts are higher lands, having good natural drainage, mainly to the south and south-east, although a small portion drains to the north-east. We see no special difficulty in supplying this section with such storm water drains laid in natural channels to points outside the limits of the tract, to convey away the surplus water from pavements and roofs; and believing this development will come in the natural order of events we have not, therefore, projected storm water improvements in this district. The data for this purpose can be best determined when the extent and character of the improvements in the section become better advanced. (See plate A for proposed and present West Side storm water drains.)

ESTIMATED COST OF THE STORM WATER DRAINAGE SYSTEM FOR THE WEST SIDE OF THE SCIOTO RIVER.

Present Requirement.

Pumping Station:		
Land	$ 5,000 00	
Building and foundation	9,000 00	
Suction tunnel, etc	1,850 00	
Machinery	20,000 00	
Add 10%	3,585 00	
		$39,435 00
Connections:		
River crossing pipes	$10,640 00	
East Side intercepting sewer connection	4,150 00	
Force mains to beds	2,440 00	
Switch and road	10,200 00	
Add 10%	2,743 00	
		30,173 00
Outlet and Interceptors:		
Main drain, Stimmel Road	$25,900 00	
Outlets and interceptors	4,750 00	
Add 10%	3,065 00	
		33,715 00
Levee north of Greenlawn avenue		6,200 00
Total cost		$109,523 00

PART III.

The Sanitary Sewerage of that Portion of the City Lying West of the Scioto River.

Enough has been said of the increased cost of sewage purification, due to the combined system, to show the economic necessity of providing the West Side of the city with the separate system of sewers; and in accordance with these ideas we have laid out a complete system of sanitary sewers for the entire district, covering all the streets and alleys now open, and providing capacity in the mains and outlet sufficient for all of the streets which may be opened in the future.

OUTLET.

As has been before said, our studies have shown that an efficient sanitary system can be designed with an outlet at the Stimmel road and the Scioto river, at such an elevation that for certain months in the year gravity flow can be obtained, while during another portion of the year, when the sewage has to be pumped to the purification beds, the lift will be materially less than would be the case with the original so called "dry flow" sewer.

The elevation of the bottom of this proposed new sanitary sewer at its outlet will be eight feet above city datum, while the extreme low water at this point is about 7½ feet. When the water in the river rises to an elevation of 8½ feet above datum, there is ample dilution in the river for the estimated sewage of the present population of the West Side. At an elevation of over ten feet above datum in the river, the sewage will have to be pumped. The average stage of the river at this point for the entire year is about nine feet above datum.

GENERAL FEATURES OF THE SYSTEM.

The main sanitary sewer will run west from the outlet on the Stimmel road to Jackson pike. At this point the sewer will ultimately branch into two main sewers, one of which will pass to the northwest beside the Renick run sewer, and

reach the intersection of Sullivant and Yale avenues, while the second branch will run north on the Jackson pike to Sullivant avenue, thence west on that avenue and the alley south of same to the corner of Yale avenue, before mentioned. For the present only the sewer in Jackson pike is recommended to be built, and is so arranged as to bring all the sewage to the outlet until the other branch main is complete. This is accomplished by slightly increasing the size of the sewer in Sullivant avenue and the alley south, above what would be its normal size. Considerable advantage is derived from a sanitary standpoint by this arrangement, in that the present amount of the sewage has a channel more nearly proportioned to its capacity than would otherwise be the case. The size of the eastern branch in Jackson pike recommended to be laid first will be 36 inches in diameter. At the corner of Yale and Sullivant avenues, the main sewer will divide, one branch continuing west on Sullivant avenue to the city limits, receiving the sewage of the State Institution for Feeble Minded Youth, and furnishing an outlet for the high land west of the same. The size of this main is gradually reduced as it approaches the city limits, corresponding to the area to be drained.

The other branch, leaving Sullivant avenue in the alley west of Yale avenue, will run north to Town street, west in Town street to the alley west of West Park avenue, north in this alley to the alley north of Broad. Near Central avenue the size will be 27 inches in diameter. Here it again divides, one branch running west in the alley near Broad street, and taking the sewage from the Columbus State Hospital, while the other branch will run north and sewer the lands adjacent to the quarry pike road, thence following dry run to the high lands west of the last named institution.

An alternative route has been surveyed connecting the Broad street sewer with the high lands west of the Institution by means of a sewer crossing the Columbus State Hospital grounds, and incidentally connecting with the main drain from the main building. This latter route is to be preferred if the right of way can be obtained.

For the service of the eastern and more thickly settled portion of the territory, a branch sewer will leave the main sewer and run north in Davis street to Town street, with a

diameter of 24 inches. At this point it will divide, one branch running west in Town street, and north in Richard and Hartford streets, with a diameter of 18 inches, to the alley north of Broad, where two smaller branches sewer the territory north of that street. Another branch, leaving the sewer at Davis and Town street will find its way by a number of turns to Chapel street, and will run thence east to Mitchell street, where it will intercept the present sewer in that street. Other branches from this sewer will intercept the present Town street sewer at Mitchell street, the present Mill street sewer at Chapel street, and the present sewer in the alley south of Broad street at Gift street. These interceptions will be so constructed as to admit only the dry weather flow of sewage from those old sewers to the proposed sanitary sewers.

The capacity of the system has been computed on the basis that the entire district served is fully built up with a population of 20,000 per square mile, and in addition to the sewage, which is estimated at 113.3 gallons per day per person, an allowance of about 43 per cent. of the sewage is added to provide for the percolation of ground water into the sewers. The results are shown in the following table:

TABLE SHOWING UNIT QUANTITIES USED IN THE DESIGN OF THE SANITARY SYSTEM.

For each 100 foot of sewer, accommodating 25 persons:

0.00437	cubic feet	per second	sewage flow.
0.00187	"	"	seepage "
0.00625	"	"	total "

For each mile of sewer, accommodating 1,250 persons:

0.2187	cubic feet	per second	sewage flow.
0.0938	"	"	seepage "
0.3125	"	"	total "

For each acre, accommodating 31 persons:

0.005342	cubic feet	per second	sewage flow.
0.002470	"	"	seepage "
0.007812	"	"	total "

For each square mile, accommodating 20,000 persons:

3.50	cubic feet	per second	sewage flow:
1.50	"	"	seepage "
5.00	"	"	total "

The smaller branch sewers are computed to carry this total amount when running only one-half full; the larger

pipe and brick mains are estimated to flow about three-quarters full.

No branch sewer of less than eight inches diameter is advocated, although a less size is often theoretically adequate for many locations; stoppages are found to increase rapidly in smaller sizes than eight inches.

In computing the size of the sewers, the well known formula of Ganguillet and Kutter has been followed, using a coefficient "N" for roughness of the interior surface equal to .013, both for pipe and brick sewers.

GRADES.

The grades given are such that over a portion of the districts there will be obtained a velocity of three to four feet per second when the sewers are flowing full or half-full; some of the smaller main sewers on the bottom lands have grades which will give 2.60 feet velocity per second when carrying the estimated flow. When running one-fourth full, these sewers will have velocities of 18 inches per second.

The main outlet sewer south of the city limits has a velocity when carrying the estimated flow of 2.85 feet per second.

This question of the velocity is an important one in the proper design of a sewer system, as upon the velocity depends the sanitary condition of the sewers. A low velocity allows the suspended matters in the sewage to be deposited on the bottom and to decompose there, creating foul and offensive conditions. It is very desirable, therefore, that grades should be given which will produce self cleaning velocities, not alone when the sewers are full, but when they are carrying the least flow. A velocity of three feet per second with sewers running full or half full is always recommended; and where such a velocity can be obtained without undue sacrifice, it is exceedingly desirable. Experience shows, however, that 2.50 feet per second when flowing half full, will largely prevent the deposit of sediment in sanitary sewers, especially where they are to be well filled from the commencement of their service. In order that the effect of the grades selected may be understood, the following table is given, compiled from careful researches made in England upon this question:

TABLE SHOWING DATA FOR MINIMUM VELOCITIES IN SEWERS.

Proportion of Sewer Filled.	Relative Velocity.	Relative Disch'rge.	Velocity For Different Depths in Feet Per Second.											
Full.	0.86	.916	**1.00**	**1.25**	**1.50**	**2.00**	**2.25**	**2.50**	**2 75**	**3.00**	**3.25**	**3.50**	**3.75**	**4.00**
Eighty-one one hun.	1.00	.924	**1.16**	**1.45**	**1.74**	**2.31**	**2.60**	**2.90**	**3.20**	**3.49**	**3.79**	**4.07**	**4.36**	**4.65**
One-half	0.86	.45	**1.00**	**1.25**	**1.50**	**2.00**	**2.25**	**2.50**	**2.75**	**3.00**	**3.25**	**3.50**	**3.75**	**4.00**
Four-tenths	0.76	.302	*0.88*	**1.10**	**1.32**	**1.76**	**1.99**	**2.20**	**2.41**	**2.65**	**2.87**	**3.09**	**3 32**	**3.52**
Three-tenths	0.64	.168	*0.74*	*0.93*	**1.12**	**1.48**	**1.67**	**1.86**	**2.05**	**2.23**	**2.42**	**2.61**	**2.79**	**2.99**
One-fourth	0.57	.118	*6.64*	*0.83*	*0.99*	**1.32**	**1.49**	**1.66**	**1.82**	**1.99**	**2.15**	**2.32**	**2.48**	**2.65**
Two-tenths	0.48	.072	**0.56**	*0.69*	*0.83*	**1.11**	**1.25**	**1.39**	**1.53**	**1.65**	**1.81**	**1.95**	**2.09**	**2.25**
One-tenth	0.28	.016	**0.32**	**0.40**	*0.49*	*0.65*	*0.73*	*0.81*	*0.89*	*0.98*	**1.05**	**1.14**	**1.22**	**1.30**

All Velocities indicated by figures in type like 2.00, etc., will move the following substances:

Coarse Ballast ..... 2 ft. 0 in.
Sea Shingle ..... 2 " 2 "

All Velocities indicated by figures in type like 0.56, etc., will move the following substances:

River Mud, semi-fluid ..... 0 ft. 3 in.
Brown Pottery Clay ..... 0 " 3½ "
Gravel, size of Small Seeds ..... 0 " 4½ "

All Velocities indicated by figures in type like 0.88, etc., will move the following substances:

Common Clay ..... 0 ft. 6 in.
Gravel, size of Peas ..... 0 " 7½ "
Yellow Sand, loamy ..... 0 " 8½ "

All Velocities indicated by figures in type like 1.00, etc., will move the following substances:

Common River Sand ..... 1 ft. 0 in.
Gravel, size of Beans ..... 1 " 6 "

PRACTICAL CONSIDERATIONS AFFECTING VELOCITY.

In selecting the lowest practicable velocity in some of the main sewers, we have been governed by consideration which seems to warrant some further explanation.

1st. The outlet, as has been elsewhere shown, can be placed at such a level that pumping is necessary only during floods, or at such times as the sewage must be lifted to the purification works.

2nd. Artificial flushing can be provided for in the main sewer by cast iron pipe connections with the storm water sewers, at the Harrisburg pike and Jackson pike, and near the corner of Broad street and Central avenue. We are of the opinion, however, that with the grades given, flushing will be needed but seldom. We estimate that the main sewers will run one-fourth full the second year, thus insuring a least velocity in the flattest grade of 18 inches per second. This velocity is quite sufficient to prevent deposits taking place.

3rd. If we attempt to increase the velocity even slightly, we sacrifice the advantage of emptying the sewer at ordinary stages of water by gravity, and with this advantage lost we should consider it desirable to put the velocities at three feet per second.

We find that with such velocities the depth of the outlet would be from 15 to 22½ feet below the level of low water in the river at Stimmel road outlet. If the branch sewers should be planned to have the same velocity as the mains, the deeper point mentioned would have to be reached. But if the flush tanks were depended on to keep the branches clean and only the mains designed with three feet velocity, 15 feet would be sufficient. Now we find that the cost of pumping all the sewage of this district when fully built up, this extra depth, would, at the rate used elsewhere in this report, amount to $8,300.00 per annum, or about $700.00 per mile of main sewer.

The cost of cleaning the sewers of Chiago in 1895, excluding the cost of cleaning catch basins, was $64 per mile, the cleaning being largely done by portable flush tanks. The sewers of that city are generally provided with less grade than proposed for the West Side. So that as a financial operation it is evident that there is a point at which it is

cheaper to clean sewers than to pump them. There is, however, this difficulty to be considered, that the pumping, if arranged for, must of necessity be done, while the cleaning is very often apt to be neglected, to the great detriment of the condition of the sewer.

4th. The character of the soil of the West Side is such that it is very doubtful if a main sewer could be laid at the depth required for a velocity of three feet per second, and be properly constructed so as to be free from an undue proportion of infiltering ground water. As a matter of fact, the attempt has already been made in the case of the so called "dry flow" sewer, and has resulted in failure.

As a result of the studies of several alternative plans, such as the Shone system, secondary pumping stations, and other methods, we feel warranted in adopting the grades and velocities before mentioned, as far more satisfactory in every respect than any other method that can be devised for the removal of sewage.

FLUSH TANKS.

Automatic flush tanks are recommended to be placed at the upper end of each branch sewer, and connected with the water works street main; from 250 to 300 gallons of fresh water should be emptied into the sewers by means of these tanks, at least once each 24 hours. Where streets have few house connections such service will keep the branch sewers in good sanitary condition, especially in the earlier years of their use, when the flow of sewage proper is not sufficient to be self-cleaning. After a sufficient number of house connections are made so that the sewage aided by the closet flush tanks from the houses adjacent can effectively keep the sewer in good condition, the street flush tanks may be operated less frequently, and in some cases be discontinued except for occasional use. 107 of these flush tanks will be required for the sewers now laid out. (See plate "B" back of pamphlet for map showing proposed West Side sanitary sewers.)

MANHOLES.

A sufficient number of manholes is necessary to enable the sewer to be conveniently inspected, repaired or cleaned at any time. Sewers that cannot be entered should have manholes not more than 200 feet a part, and the sewers should be

straight between manholes, both in line and grade, so that when looking through them from manhole to manhole, the aperture should appear as a perfect circle. Manholes should be located at all street junctions, changes of line and grade, and at the end of all branch sewers. One thousand and seventy-six manholes have been located on the plans; they should be constructed of brick masonry with heavy perforated iron covers, and provided with ladder irons.

STREET AND HOUSE CONNECTING JUNCTIONS.

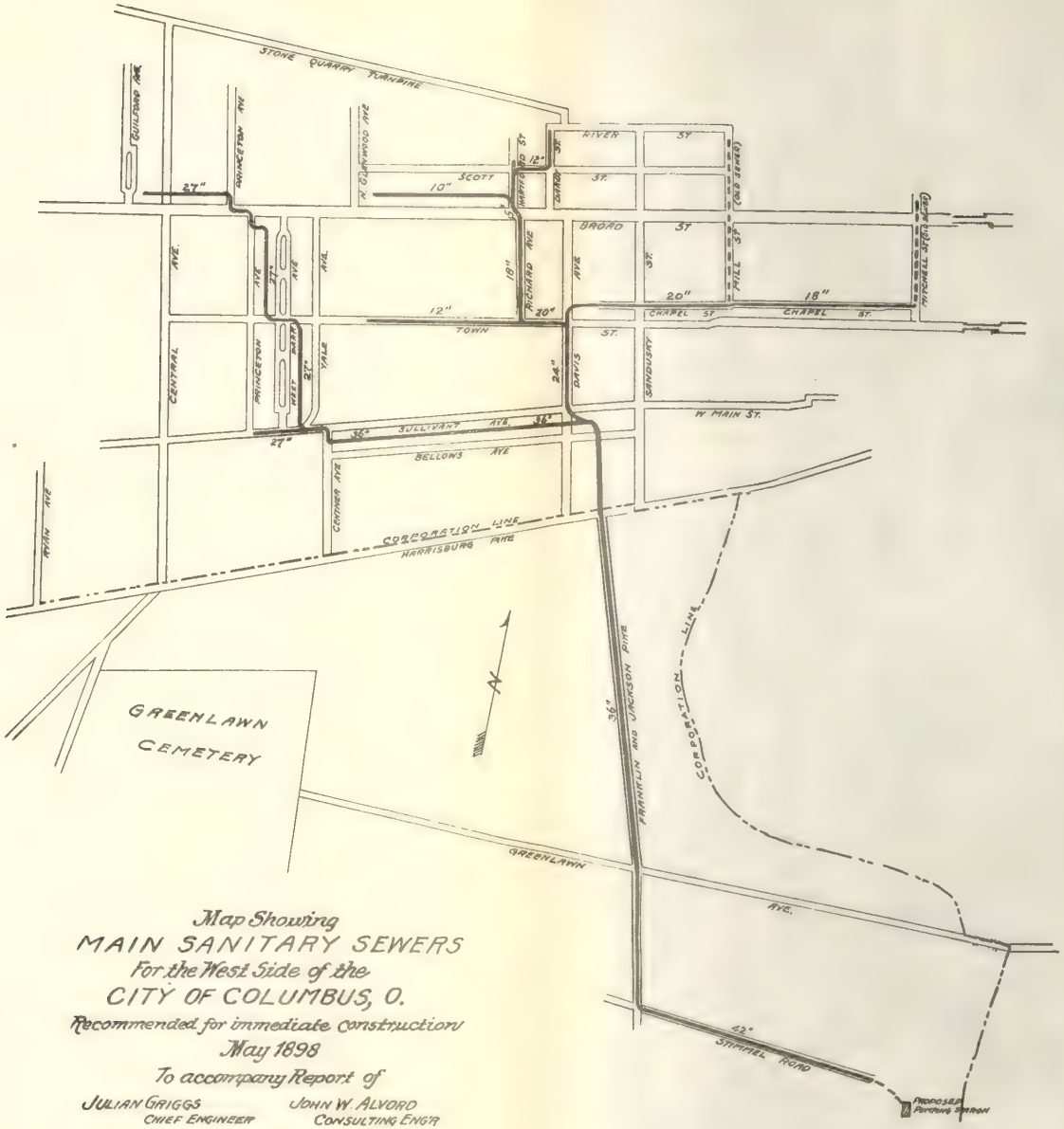
House connection junctions should be set in the sewer during construction, and temporarily closed by being blocked off with brick and cement; they should be six inches in diameter, and a usual rule is to locate them 15 feet inside of the down stream lot line, referring to the sewer's flow. They should be recorded for future reference. All street connection junctions for future extensions or branches, should be carefully set in the sewer during construction.

INTERCEPTORS.

Special plans are provided for intercepting the dry weather flow of a number of the older sewers, and utilizing them partially as sanitary sewers. Where such old sewers are connected with the new sanitary system they should have a sufficient number of new manholes built upon them to enable them to be carefully inspected and repaired. A flush tank should be built upon the upper end of all old sewers so connected, and no sewer should be connected that is liable to run deposits of sand, gravel or other injurious matter into the sanitary system.

DEPTH.

The depth of the system in general is such as to allow of cellars throughout the entire district. A depth of seven feet for residential streets and from eight to ten feet for business streets, measured from the street grade to the bottom of the sewer, has been generally obtained. In several necessary cases this depth has been reduced to 6 feet, and in one or two instances to five feet at the upper ends of certain branches, but only where it is evident the grade of the adjacent streets when established, must be raised.



Map Showing

MAIN SANITARY SEWERS

For the West Side of the

CITY OF COLUMBUS, O.

Recommended for immediate construction

May 1898

To accompany Report of

JULIAN GRIGGS, CHIEF ENGINEER — JOHN W. ALVORD, CONSULTING ENGR

SCALE 1 INCH = 1200 FEET

PORTIONS TO BE FIRST CONSIDERED.

It will be some years before the entire system as laid out will be constructed, and in view of the needs of the present population, we would recommend that the 5.7 miles of main sewers shown on the accompanying plan receive early consideration. The proportional amount of their cost is estimated at $72,763,50.

(For map of sanitary main sewers recommended for immediate construction, see Inset facing page 92.)

ESTIMATES.

The subjoined estimates give in detail the cost of the different sewers, their average depth, and number of manholes and flush tanks, so that any sewer or combination of sewers can be selected from the list and their aggregate cost readily ascertained.

In estimating the branch sewers, it has been thought desirable to group them into districts for comparison.

The total cost of the system as laid out is as follows:

12.2 miles main sewers	$121,729 80
40.6 miles branch sewers	165,011 00
Total	$286,740 80

These amounts will make the mains cost an average of about $10,000 per mile, and the branches an average of $4,000 per mile. The latter, if assessed wholly against the property, would be estimated about as follows:

FOR ONE MILE OF SEWER.

Length of both sides of the street		10,560 feet.
Deduct 24 streets 66 feet wide	1,584 feet.	
" 16 alleys 16 feet wide	256 "	
" 16 corner lots 125 feet deep	2,000 "	3,840 "
Available for taxation		6,720 "

Dividing into the cost per mile of the branch sewers, will give us 59½ cents per front foot, or $23.80 per forty foot lot. To this should be added about 5 per cent. for expenses, as locally charged, bringing the total cost per 40 foot lot up to $24.99, or in round numbers to $25 per lot.

This assumption is based upon average conditions; in certain localities the cost will be higher, and in others lower.

ESTIMATE OF COST OF MAIN SEWERS OF THE WEST SIDE SANITARY SYSTEM—AS DESIGNED.

Street or Alley.	Size—inches.	Length—feet.	Cut—feet.	No. of Manholes.	Cost per Foot Exclusive of Manholes.		Total Cost.
					Trench.	Sewer.	
Stimmel Road	42	2,800	12.0	....	$0.86	$2.30	$8,848 00
Jackson Pike	36	1,700	12.0	4	86	2.00	4,862 00
" "	36	3,200	14.0	10	1.06	2.00	9,792 00
" "	36	1,400	18.0	3	1.52	2.00	4,928 00
" "	36	1,400	24.6	3	2.50	2.00	6,300 00
Alley S. of Sulliv't av.	36	2,550	11.3	7	0.78	2.00	7,089 00
Sullivant ave	1½ ring. 27	950	10.1	2	54	1.20	1,653 00
Alley W. of Yale ave	1½ ring. 27	4,070	12.1	14	68	1.20	7,651 60
Sullivant ave	1½ ring. 24	1,240	14.5	4	88	1.05	2,393 20
Davis ave	1½ ring. 24	1,190	11.2	6	61	1.05	1,975 40
Sullivant ave	1 ring. 20	5,700	15.1	19	92	60	8,664 00
" "	20	1,360	12.7	4	73	60	1,608 80
Cent'l av. & stone qry p'k	Pipe. 20	4,860	14.2	24	84	55	6,575 40
Asylum Grounds	20	1,815	10.0	9	54	55	1,978 35
Chapel street	20	2,120	13.5	10	80	55	2,862 00
Alley north of Broad st.	18	1,930	11.8	10	68	45	2,180 90
Richard ave	18	1,635	10.0	8	54	45	1.618 65
Asylum Grounds	18	6,285	10.0	32	54	45	6,222 15
Chapel street	18	2,175	9.2	10	47	45	2,001 00
Broad street	18	1,000	13.6	6	80	45	1,250 00
Sullivant ave	15	300	13.5	1	55	35	270 00
" "	15	1,700	13.8	8	55	35	1,530 00
Glenwood "	15	2,500	6.5	9	16	35	1,275 00
Hartford "	15	725	11.4	4	47	35	594 50
Eldon "	15	1,600	12.0	8	50	35	1,360 00
Alley north of Mound st.	12	900	13.4	4	55	25	720 00
Darby street	12	1,025	10.9	5	45	25	717 50
Town street	12	450	10.3	3	39	25	288 00
Glenwood Boulevard	12	250	13.0	1	55	25	200 00
Eldon avenue	12	2,800	12.0	14	50	25	2,100 00
Grace "	12	3,100	12.0	16	50	25	2,325 00

Total cost exclusive of manholes	$102,213 45
Two hundred and sixty manholes at $32.50	8,450 00
Total cost including manholes	$110,663 45
Add 10 per cent. for engineering and contingencies	11,066 35
Total estimated cost	$121,729 80

ESTIMATE OF COST OF LATERAL SEWERS FOR THE WEST SIDE SANITARY SYSTEM.

(WITHIN THE CORPORATE LIMITS.)

For the purpose of estimating the lateral sewers of the sanitary system, the territory has been divided into six more or less arbitrary districts as follows:

"A" Bounded on the north by the Scioto river; on the west by the alley west of Schultz avenue; on the south by Broad street; and on the east by Mill street.

"B" Bounded on the north by Broad street; on the west by Central avenue; on the south by Sullivant avenue; and on the east by Grubbs street.

"C" Bounded on the north by Broad street and Scioto river; on the west by Grubbs street and Mill street; on the south by Main street and the Scioto river; on the east by Scioto river.

"D" Bounded on the north by Sullivant avenue; on the west by Ryan avenue; on the south by Harrisburg pike; on the east by McDowell street.

"E" Bounded on the north by Broad street; on the west by Hague avenue; on the south by Sullivant avenue; on the east by Central avenue.

"F" Bounded on the north by the north corporation line; on the west by Hague avenue; on the south by Broad street; on the east by the alley west of Schultz avenue.

ESTIMATE OF THE COST OF THE LATERAL SEWERS OF THE WEST SIDE SANITARY SYSTEM—AS DESIGNED.

Districts.	Length of Laterals.	No. of Manholes.	No. of Flush Tanks.	Cost per Foot Inclusive of M. H. & F. T.	Total Cost.
"A"	31,000	155	15	$0 70	$21,700 00
"B"	46,200	231	23	70	32,340 00
"C"	25,000	125	13	70	17,500 00
"D"	28,700	145	15	70	20,090 00
"E"	65,900	330	33	70	46,130 00
"F"	17,500	90	9	70	12,250 00
Total	214,300	1,076	108	.....	$150,010 00
Add 10 per cent. for engineering and contingencies					15,001 00
Total cost					$165,011 00

Total length of mains planned ..... 12.2 miles.
Recommended for immediate construction ..... 5.7 "
Total length of laterals planned ..... 40.6 "

ESTIMATE OF COST OF MAIN SEWERS RECOMMENDED FOR IMMEDIATE CONSTRUCTION.

WEST SIDE SANITARY SYSTEM.

Street or Alley.	Size—inches.	Length—feet.	Cut—feet.	No. of Manholes.	Cost per Foot Exclusive of Manholes.		Total Cost.
					Trench.	Sewer.	
Stimmel Road, Scioto River to Jackson Pike.	42	2,800	12.0	7	$0.86	$2.30	$8,848 00
Jackson Pike—							
Stimmel Road, north.	36	1,700	12.0	4	86	2.00	4,862 00
" " "	36	3,200	14.0	10	1.06	2.00	9,792 00
" " "	36	1,400	18.0	3	1.52	2 00	4,928 00
" " "	36	1,400	24 6	3	2.50	2.00	6,300 00
Alley S. of Sullivant av.	36	2,550	11.3	7	78	2.00	7,089 00
Sullivant ave. to alley east of Princeton.....	27	400	10.0	1	54	1.20	696 00
Alley west of Yale to Sullivant ave., north.	27	4,070	12.1	14	68	1.20	7,651 60
Alley north of Broad to alley west of Central.	18	400	11.8	1	68	45	452 00
Davis ave. from Sullivant north	24	1,190	11.2	6	61	1.05	1,975 40
Richard av. from Town to Broad.....	18	1,635	10.0	8	54	45	1,618 65
Hartford ave., Broad to Scott.....	15	725	11.4	4	47	35	594 50
Darby and Scott streets to River street	12	1,025	10.9	5	45	25	717 50
Chapel st., from Davis to Gift street	20	2,120	13.5	10	80	55	2.862 00
Chapel street from Gift to Belle street.	18	2,175	9.2	10	47	45	2,001 00
Town street, Martin to alley E. of Glenwood..	10	1,320	11.0	6	45	20	858 00
Al. N. of Broad, Hartf'd to al. E. of Glenwood.	10	1,600	11.0	8	45	20	1,040 00
Town st., Richard to al. west of Martin ave....	12	450	10.3	3	39	25	288 00
		30,160		110			$62,573 65
Add 110 manholes at $32.50							3,575 00
Total cost, including manholes.....							$66,148 65
Add 10 per cent. for engineering and contingencies.....							6,614 85
Total estimated cost.....							$72,763 50

Total number of miles recommended, five and seven-tenths.

PART IV.

Disposal of the Sewage of the Alum Creek District.

That portion of the city lying within the limits of the watershed of Alum creek has a population of about 17,000 people, largely found upon its western edge. It is drained to the creek by a combined sewer, nine feet in diameter, terminating in Main street. This sewer is intended to drain a large territory lying to the north-west of the outlet, much of which is already sewered.

ALUM CREEK.

Alum creek drains a comparatively narrow watershed of 198 square miles above Columbus. The creek is without considerable flow a large portion of the year; in summer it ceases for several months. No guagings are known, and no opportunity has been given in the limited time afforded us to make measurements of its average flow, of value for exact designs. It is assumed for the purposes of this report that the ordinary flow is insufficient to properly dilute the sewage now being emptied into it for at least nine months of the year, and during the remaining three months partial dilution only can be had.

THE SEWAGE FLOW.

The sewage flow of the nine foot sewer has been estimated in dry weather at 1,750,000 gallons each 24 hours. This corresponds fairly well with the water supply of the district. During the wet season this flow must be materially greater. The elevation of the invert of this sewer, where it empties into the creek, is 55.76 feet above city datum, while the elevation at the summit of the ridge dividing the water shed of Alum creek from that of the Scioto river at Main street, is 115.8 feet above city datum. This summit is about 1½ miles west of Alum creek, and about two miles east of the Scioto river. Immediately west of the summit there is a four foot sewer in Main street with but few branches, which drains

into the Peters' run sewer, and thence to the intercepting sewer, and Scioto river. This sewer for some reason seems not to have been developed as a main sewer, as the streets adjacent are all drained in other directions.

FUTURE OF THE DISTRICT.

The future of this district, taken as a whole, is very problematical. That portion along the western edge on the high lands, is well built up, and will probably grow towards the east with more or less rapidity. The portion of the district along the creek is as yet not settled at all, except in the vicinity of Main street. East of the creek, which is beyond the present city limits, there is but little evidence of population or present necessity for sewerage.

PROJECTS CONSIDERED.

It was at first thought that Alum creek would eventually need an intercepting sewer extending south, which might intercept other sewers from the west, not yet built. This intercepting sewer, after being extended a sufficient distance to cover all the prospective territory, might terminate in sewage disposal works, either upon land or artificial filters, or be pumped by a force main over the ridge to the west into the main intercepting sewer, and thence to the disposal work already planned. Some five square miles of territory would be thus served and its dry weather flow collected. The size of sewer required would be about four feet in diameter, opposite the driving park.

PROJECT RECOMMENDED.

We feel at this time unwilling to recommend any project which seems to be so far in the future as this would be, and after carefully considering the matter, have decided to suggest that the dry weather flow from the outlet of the present sewer in Main street be pumped back up the ridge and into the four foot sewer in Main street, flowing west to the main intercepting sewer, thence to the disposal works already planned.

This is a temporary expedient, if the population of this district increases beyond all expectation, and it is a permanent solution if the population does not materially increase, or at best is of slow growth. It will be quite inexpensive compared with any other project that might be suggested.

The main item of cost will be for a force main 7,500 feet long. Should the future growth in the course of ten or fifteen years require radical changes in the treatment necessary, the force main could be removed, recoated and put to other uses. Its depth need be but four feet below the surface, and its size between 16 and 20 inches in diameter, depending upon the results of the gaugings of the sewage flow.

GENERAL ARRANGEMENT.

In the absence of exact data, no detailed plans can be worked out at this time, but the general arrangement of the improvement can be suggested.

The pumping station will be equipped with pumps of about 2,500,000 gallons daily capacity, and should be geared pumps, driven by electric motors, supplied with current either from the city light plant or the street railway company. These motors can be made almost automatic, float valves being arranged to turn the current when the sewage sufficiently accumulates and shut off the same when the sewage is pumped to a desired level. In high water no pumping would be necessary, and a high water float set at a desired level would prevent pumping at such times. The station would require about one-half the time of one man, who would not need to be constantly on the ground. The pumps would work night and day, or 18 hours out of 24, as might be desired, but in the latter case a reservoir capable of holding six hours flow would have to be provided. The pumping station need not have a building larger than 16 feet square located on the rear of a city lot in the proper vicinity. The location of the pumping station could be west of the Norfolk & Western Railroad, at such a point as would include the population without losing fall in the sewer. The force main might be laid in Mound street, which is not yet paved, and would be of cast iron not exceeding 20 inches in diameter; it would discharge into the four foot sewer in Main street west of the dividing ridge. In wet or stormy weather this plant would not be in operation, consequently the capacity of the lower part of the sewer on the west side of the ridge which would receive the discharge would not be impaired for the service in its immediate vicinity for which it was originally intended, while in dry weather, when it was desired to pump the Alum creek sewage, this sewer would have ample cap-

acity to do its work and would have its sanitary condition materially improved by the increased volume.

The total lift of the pumps would not exceed 70 feet if but one pumping station is used; it may prove better economy when the flow of the sewer is accurately known, to divide the work between two pumping stations, one of which might be located half way up the slope, and pump all the sewage above that point, while the other could be located lower down, thus saving materially in the total work to be done and the necessary horse power to be purchased.

Such pumping stations as have been described are not necessarily offensive, and could have considerable latitude as to location.

ESTIMATED COST OF DISPOSAL OF THE SEWAGE OF ALUM CREEK DISTRICT.

PUMPING STATION.

Lot of pumping station	$600 00	
Building	1,400 00	
Triplex geared pump and motor	3,000 00	
Inlet well and connections	900 00	
Automatic appliances	250 00	
Add 10 per cent	615 00	
		$6,765 00

CAST IRON MAIN.

Cast iron main 20 inches in diameter laid in Mound street, 7,500 feet long	$15,000 00
Total cost	$21,765 00

As has been said before, no detailed plans can be made for this plant until more exact data are secured as to the flow of the sewer and the length of time dilution could be satisfactorily had in Alum creek. Such estimates as are here presented are therefore necessarily approximate and subject to revision. They will, however, give a fair indication of the comparative cost of the recommendation.

Operating expenses with electric power on the basis of 1,750,000 gallons pumped nine months, should not exceed $1,500 per annum.

ALTERNATIVE POWER.

The natural gas main passes within a short distance of this proposed location, and would furnish an alternative power to electricity—attendance would, however, be more expensive.

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Page 16. Diagram Showing growth of population in Columbus.

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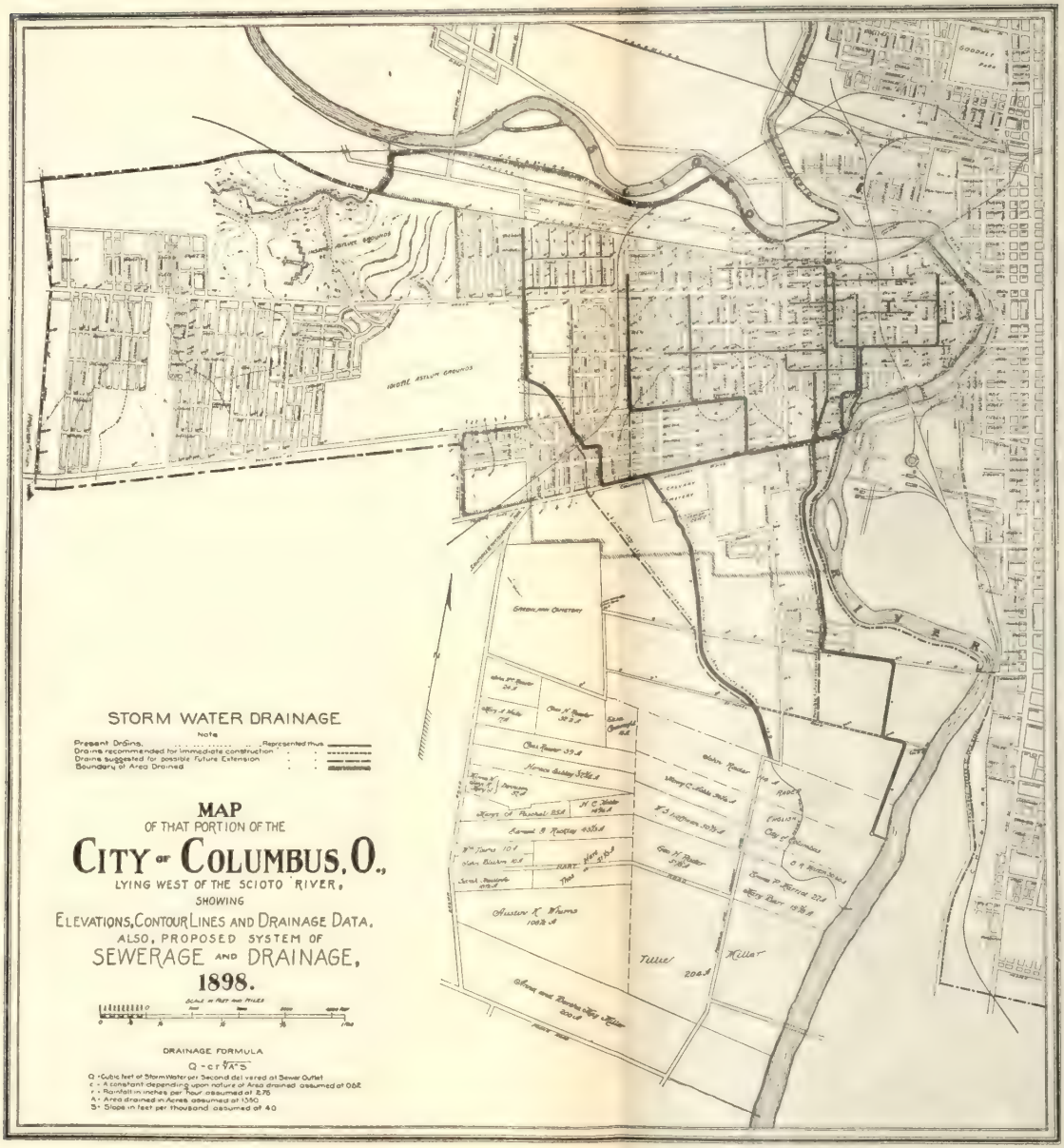
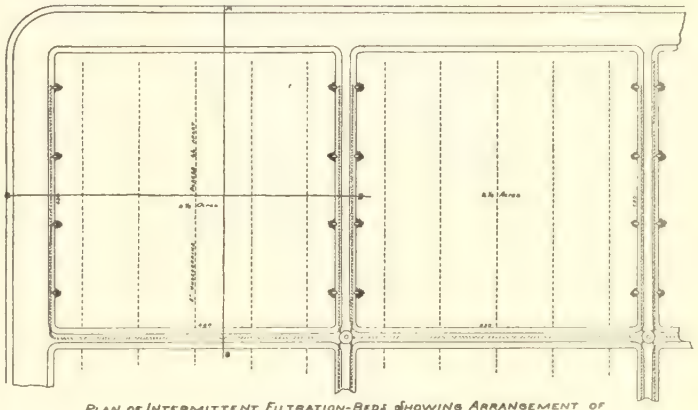
Plate 6. Plans for Valve Chambers on the Dry Flow Sewer at Stimmel road and Outlet for same near the English farm.

Plate 7. Plans for Stimmel road Connection, Outlet for McDowell street Sewer, and a 36 inch cast iron Flap Valve.


STORM WATER DRAINAGE
Note
Present Drains, ... Represented thus
Drains recommended for immediate construction
Drains suggested for possible Future Extension
Boundary of Area Drained
MAP
OF THAT PORTION OF THE
CITY OF COLUMBUS, O.,
LYING WEST OF THE SCIOTO RIVER,
SHOWING
ELEVATIONS, CONTOUR LINES AND DRAINAGE DATA,
ALSO, PROPOSED SYSTEM OF
SEWERAGE AND DRAINAGE,
1898.
SCALE IN FEET AND MILES
DRAINAGE FORMULA
Q = cr^4√A·S
Q = Cubic feet of Storm Water per Second delivered at Sewer Outlet
c = A constant depending upon nature of Area drained assumed at 0.62
r = Rainfall in inches per hour assumed at 2.75
A = Area drained in Acres assumed at 1360
S = Slope in feet per thousand assumed at 4.0
IDIOTIC ASYLUM GROUNDS
GREENLAWN CEMETERY
Tuller
Hillar

MAP OF A PORTION OF
CITY OF COLUMBUS, O.
LYING WEST OF SCIOTO RIVER
SHOWING
PROPOSED SEWERAGE SYSTEM
SCALE IN FEET & MILES
IDIOTIC ASYLUM GROUNDS
SULLIVANT AV.
GREENLAWN CEMETERY
CHAS. F. RY.
HORACE SIBLEY
HENRY C. NOBLE
W. S. HOFFMAN
GEO. H. RADER
EMMA P. MARRIOT
MARY BARR

GENERAL PLAN
SHOWING PROJECT FOR DISPOSAL OF THE SEWAGE OF THE
CITY OF COLUMBUS, O.
BY
BROAD IRRIGATION & INTERMITTENT FILTRATION
BETWEEN THE
SCIOTO RIVER & OHIO CANAL
ON BOTH SIDES OF THE
CLICKENOER ROAD
MARCH 1898
TO ACCOMPANY REPORT ON SEWAGE DISPOSAL
JULIAN GRIGGS CIVIL ENGINEER
JOHN W. ALVORD CONSULTING ENG.
SCALE
0 500 1000 1500
PROJECT NO. 1
SCALE 1 INCH = 660 FT.
TOTAL LAND TO BE ACQUIRED = 1288 ACRES
PROPOSED FOR SEWAGE IRRIGATION 921 ACRES
AVAILABLE FOR INTERMITTENT FILTRATION 63 ACRES
NOT AVAILABLE AT PRESENT 304 ACRES
SCIOTO RIVER
OHIO CANAL
CLICKENOER ROAD
W. BROADWAY
ALLIE & EMMA C. EVANS
W. T. SPANGLER
GERMAN VILLAGE
SOUTH PARK
MARY
CLARK
JEFFERSON
GRANT
FRANKLIN
C. F. R. R.
N
W
E
S



PLAN OF INTERMITTENT FILTRATION-BEDS SHOWING ARRANGEMENT OF CARRIERS AND DISTRIBUTION.

SCALE 1" = 80'

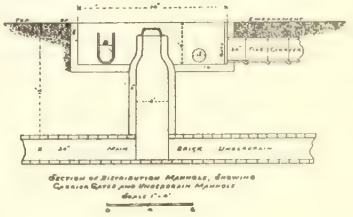
0 40 160

DETAILS FOR THE DISPOSAL OF THE SEWAGE OF THE CITY OF COLUMBUS

TO ACCOMPANY GENERAL PLAN FOR BROAD IRRIGATION AND REPORT ON SEWAGE DISPOSAL.

JULIAN GRIBBS
CHIEF ENGINEER
JOHN W. ALVORD,
CONSULTING ENGINEER

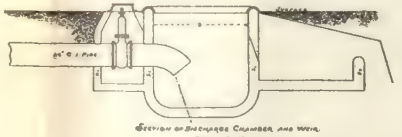
PLATE NUMBER 1



SECTION OF DISTRIBUTION MANHOLE, SHOWING GEORGIA GATES AND UNDERDRAIN MANHOLE

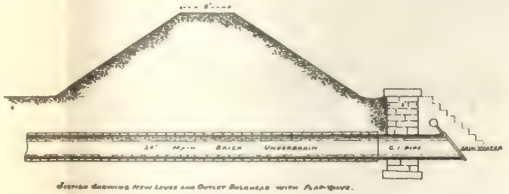
SCALE 1" = 4'

0 4 8



SECTION OF DISCHARGE CHAMBER AND WEIR.

SCALE 1" = 4'

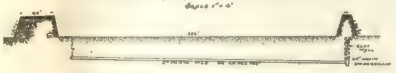


SECTION SHOWING NEW LEVEE AND OUTLET BULKHEAD WITH FLAP VALVE.

SCALE 1" = 4'

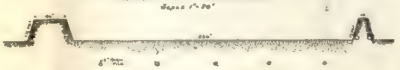
SECTION OF MAIN CARRIER DITCH AND SLUICE BOX.

SCALE 1" = 4'



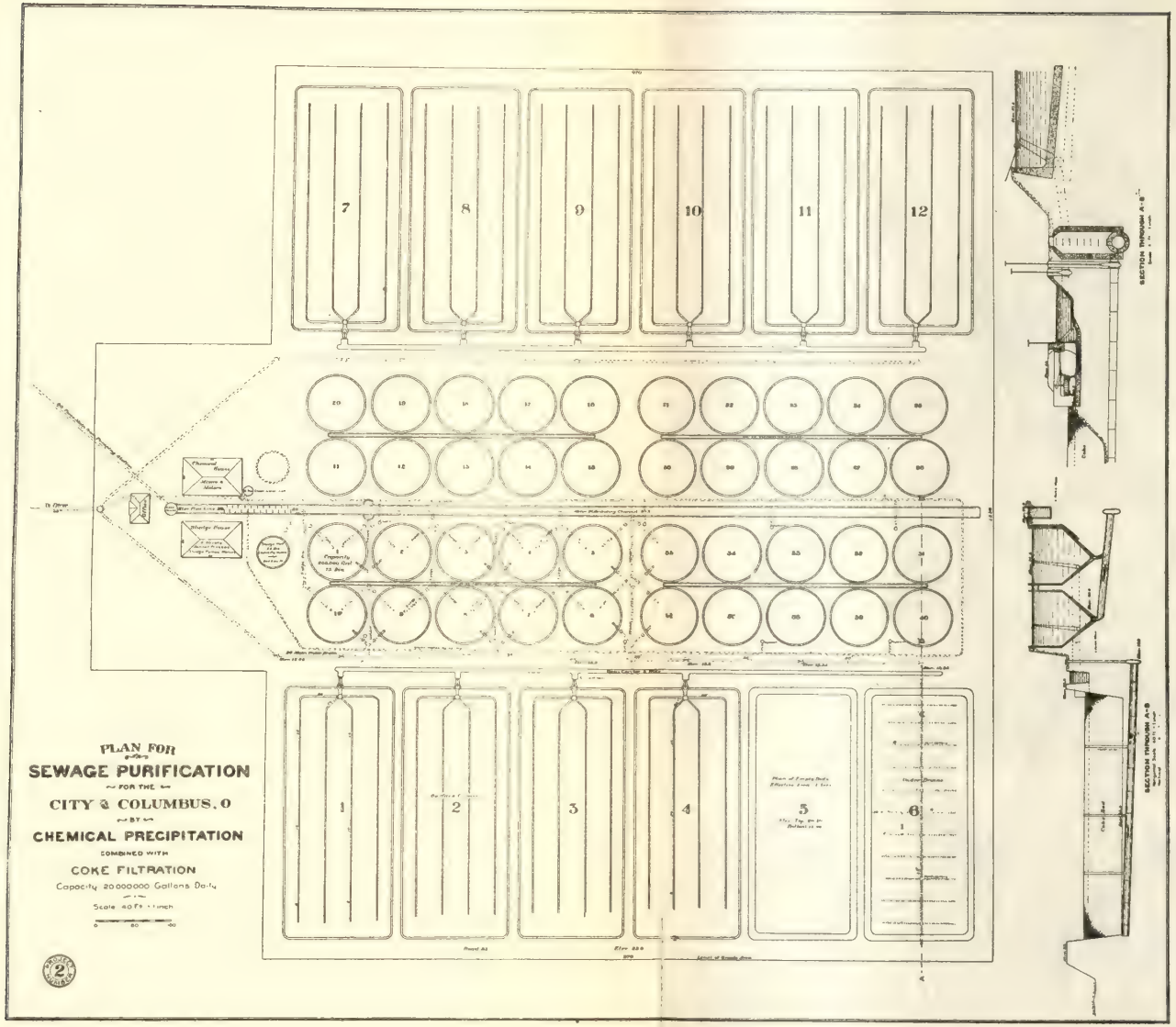
SECTION THROUGH A B OF FILTER BED SHOWING EMBANKMENT AND UNDERDRAINAGE

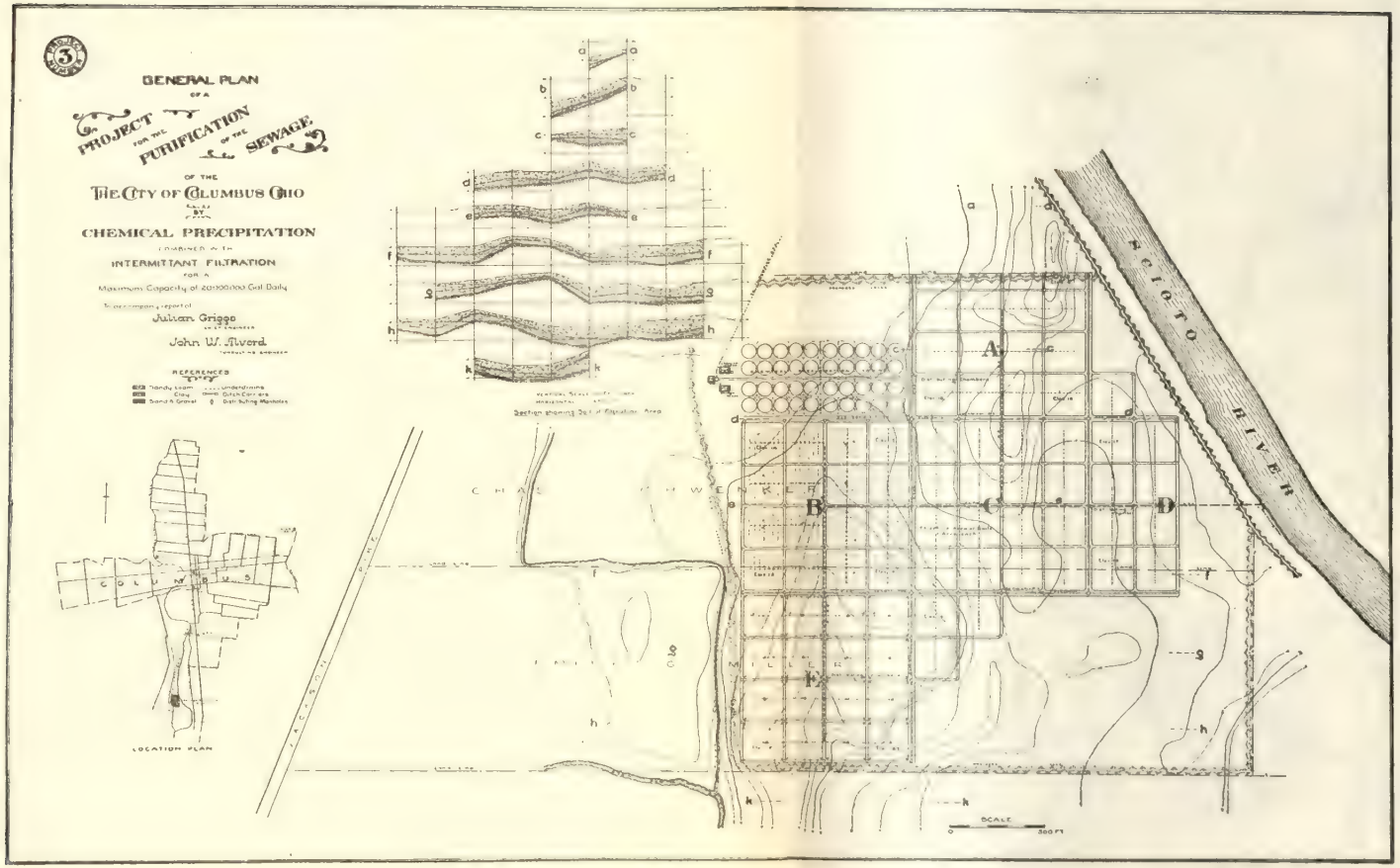
SCALE 1" = 20'

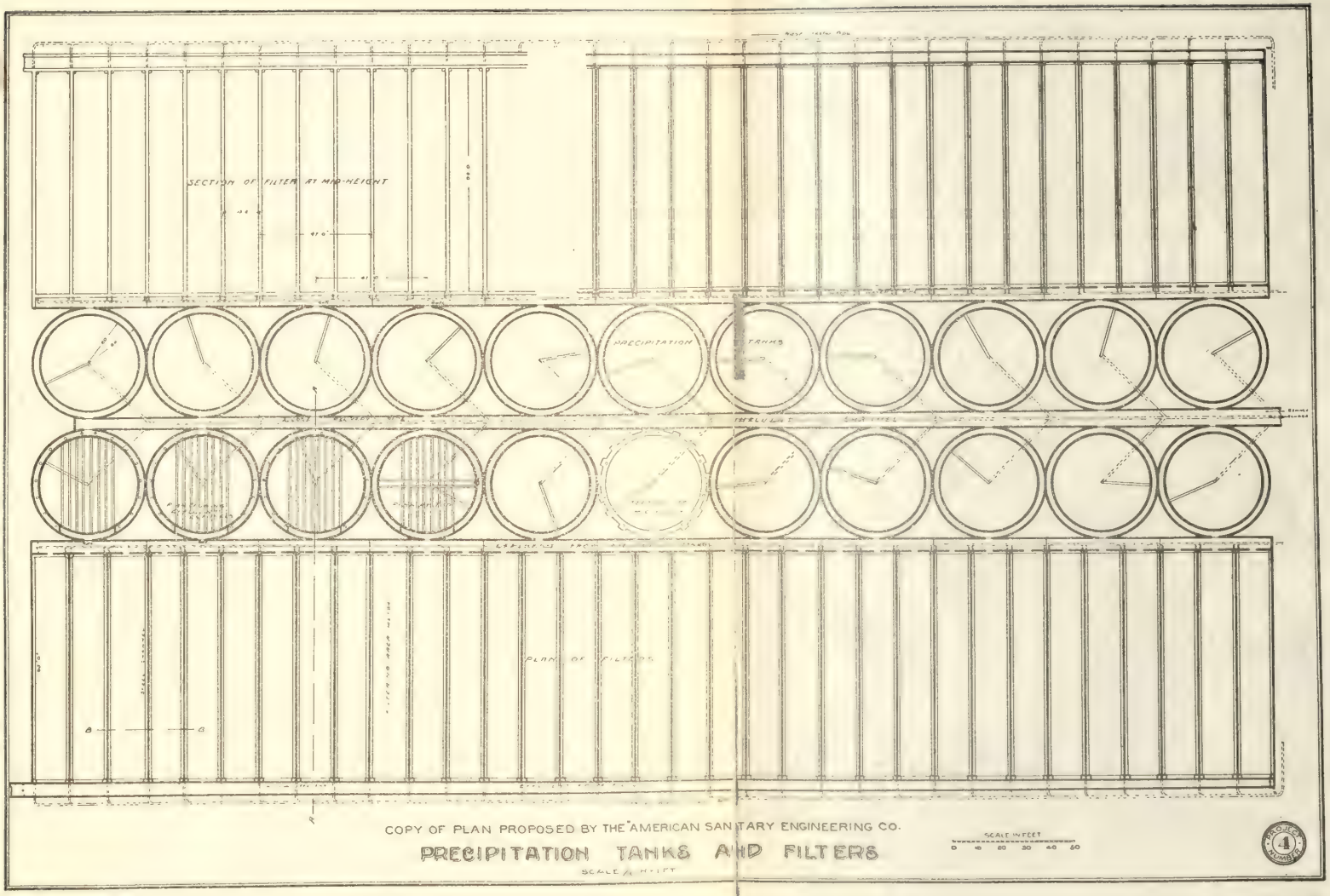


SECTION THROUGH C D OF FILTER-BED

SCALE 1" = 20'


7
8
9
10
11
12
1
2
3
4
5
6
PLAN FOR
SEWAGE PURIFICATION
FOR THE
CITY OF COLUMBUS, O
BY
CHEMICAL PRECIPITATION
COMBINED WITH
COKE FILTRATION
Capacity 20000000 Gallons Daily
Scale 40 Ft = 1 inch
0 80 160
SECTION THROUGH A-B
SECTION THROUGH A-B


3
GENERAL PLAN
OF A
PROJECT FOR THE PURIFICATION OF THE SEWAGE
OF THE
THE CITY OF COLUMBUS OHIO
BY
CHEMICAL PRECIPITATION
COMBINED WITH
INTERMITTANT FILTRATION
FOR A
Maximum Capacity of 40,000,000 Gal Daily
To accompany report of
Julian Griggs
CHIEF ENGINEER
John W. Alvord
CONSULTING ENGINEER
REFERENCES
Sandy Loam
Clay
Sand & Gravel
Underdrains
Brick Conduits
Gate Setting Manholes
Section showing Out of Operation Area
LOCATION PLAN
SCIOTO RIVER
A
B
C
D
E
F
SCALE
0
300 Ft



COPY OF PLAN PROPOSED BY THE AMERICAN SANITARY ENGINEERING CO.

PRECIPITATION TANKS AND FILTERS

SCALE 1/4 IN FT

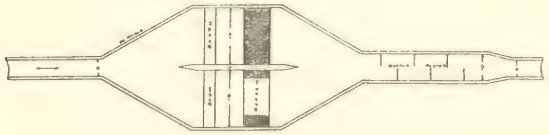
SCALE IN FEET

0 10 20 30 40 50

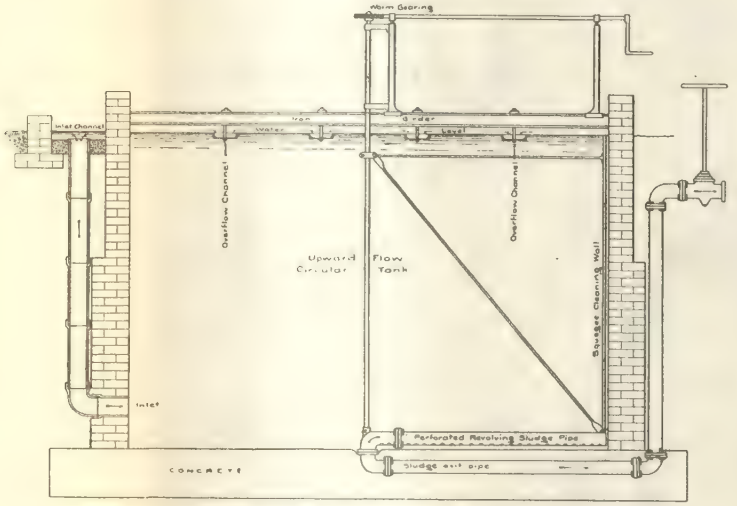
PLATE 4

SECTION A-A

SECTION B-B



PLAN OF SCREENING CHAMBER

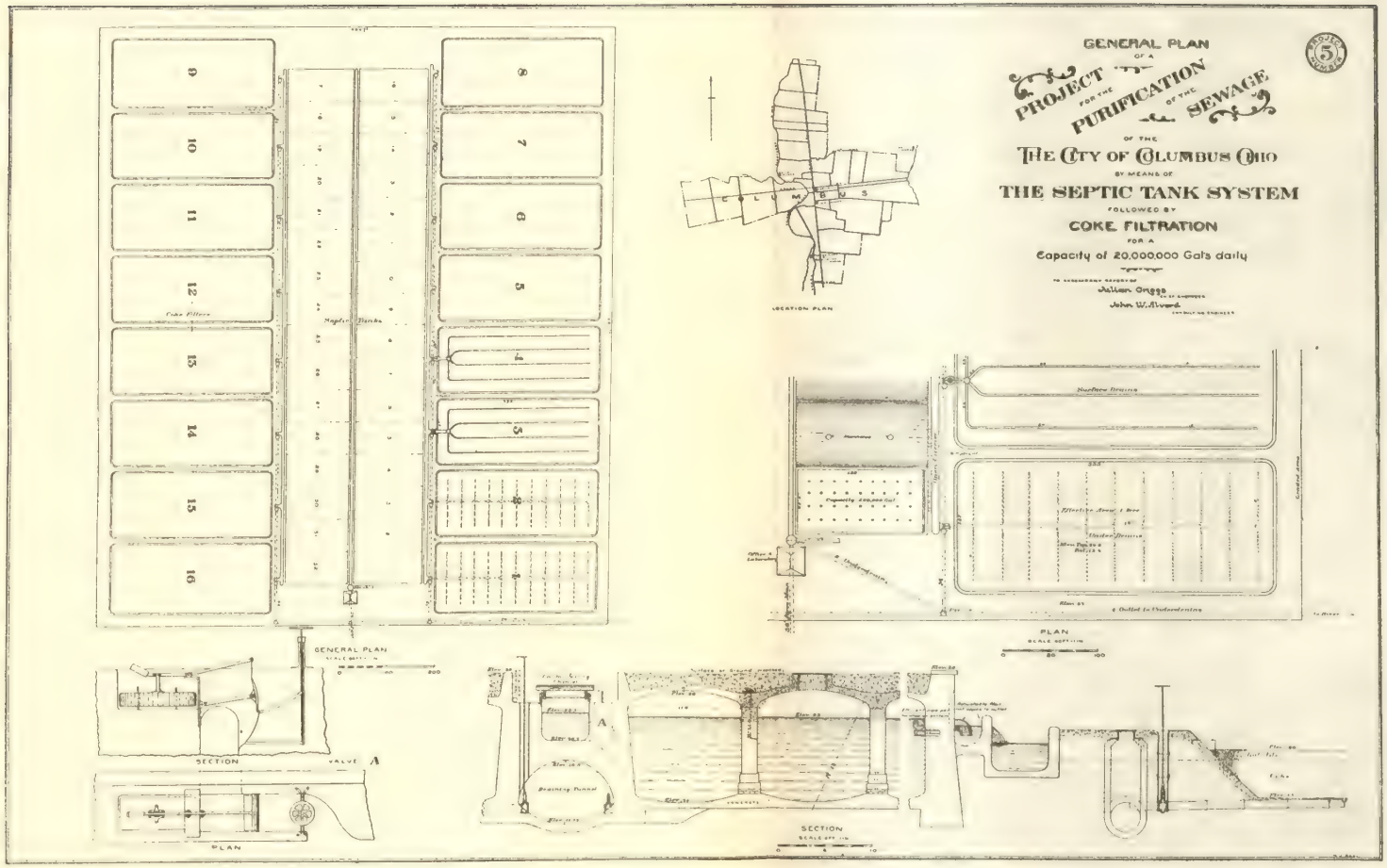


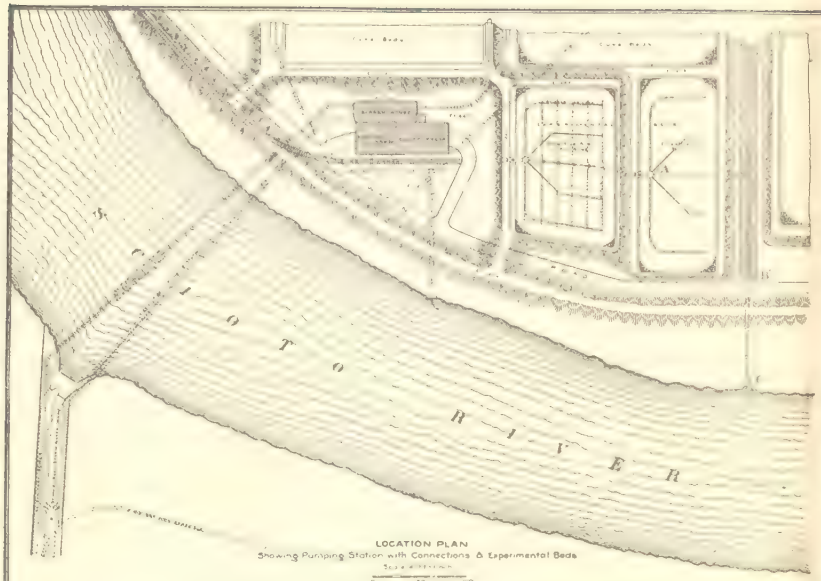
CANDY'S PATENT CIRCULAR TANK

DETAILS OF

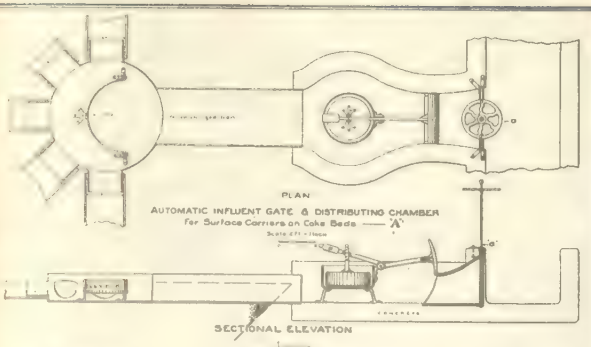
PRECIPITATION TANKS AND FILTERS

PROPOSED BY THE AMERICAN SANITARY ENGINEERING CO


GENERAL PLAN
OF A
PROJECT
FOR THE
PURIFICATION
OF THE
SEWAGE
OF THE
THE CITY OF COLUMBUS OHIO
BY MEANS OF
THE SEPTIC TANK SYSTEM
FOLLOWED BY
COKE FILTRATION
FOR A
Capacity of 20,000,000 Gals daily
Julian Griggs
John W. Alvord
LOCATION PLAN
GENERAL PLAN
SECTION
VALVE A
PLAN
PLAN
SECTION



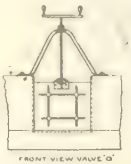
LOCATION PLAN
Showing Pumping Station with Connections & Experimental Beds



PLAN
AUTOMATIC INFLUENT GATE & DISTRIBUTING CHAMBER
for Surface Carriers on Coke Beds — 'A'

SECTIONAL ELEVATION

HALF SECTION HALF END

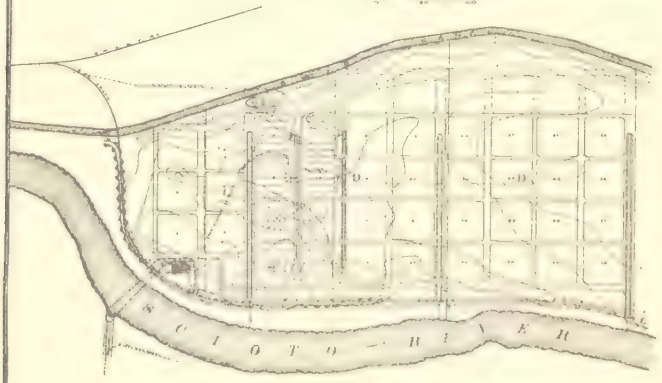


FRONT VIEW VALVE 'A'

PLAN
ADJUSTABLE WEIR
At outlet end of Effluent Ditch
'B'

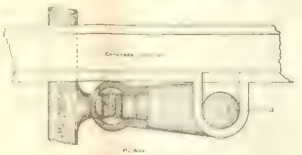
PLAN
EFFLUENT OUTLET
Showing Flap Gate & Chamber
'C'

LONGITUDINAL SECTION

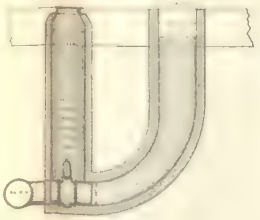


GENERAL PLAN

SECTION OF COKE BEDS
Scale 10 Ft = 1 Inch



PLAN
D



OUTLET OF FORCE MAIN
into Concrete Carrier Channel

PLAN & DETAILS
OF A

PROJECT FOR THE PURIFICATION OF THE SEWAGE

OF THE

CITY OF COLUMBUS, O.

BY

MECHANICAL SCREENING

AND

DOUBLE COKE FILTRATION

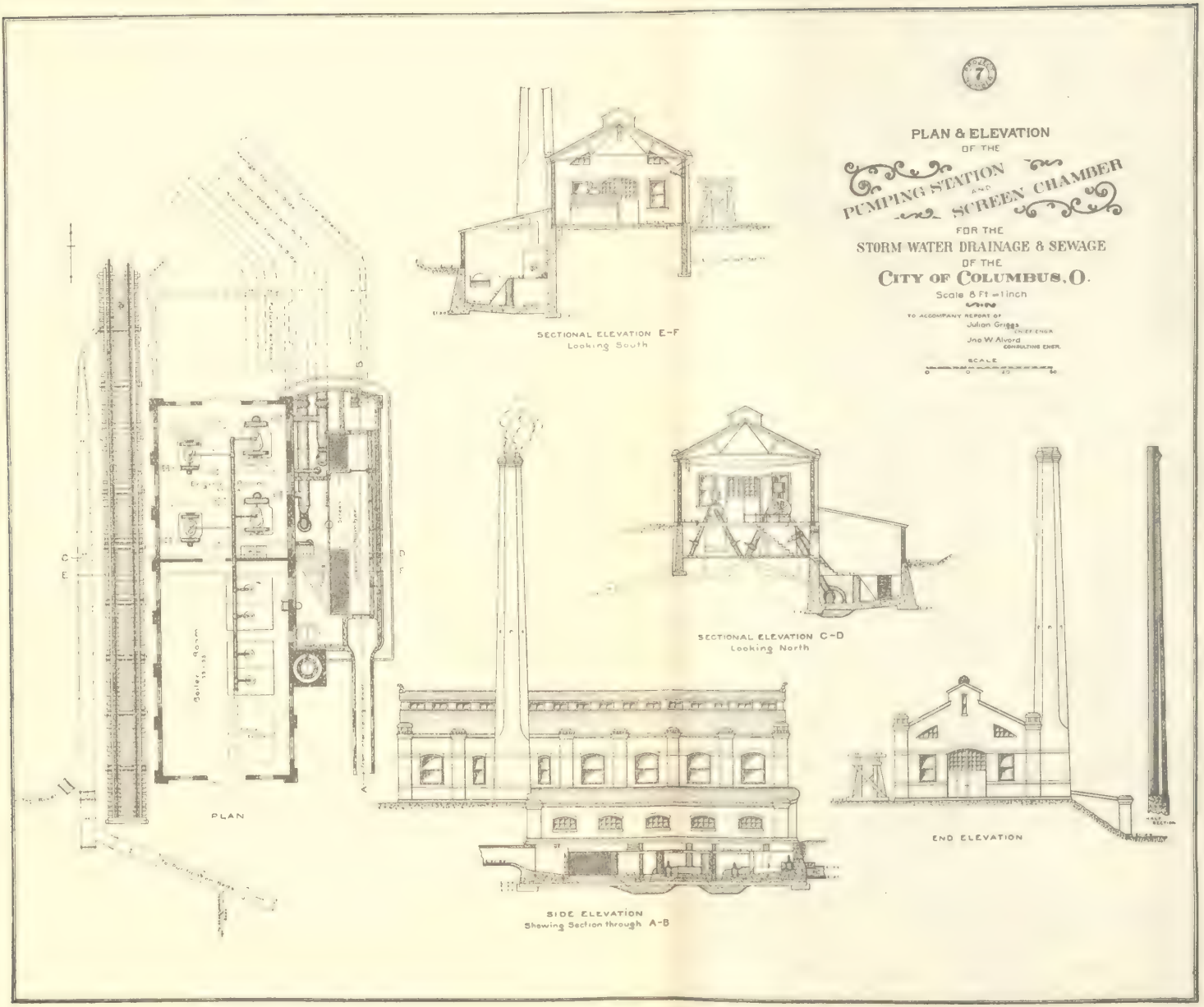
FOR A

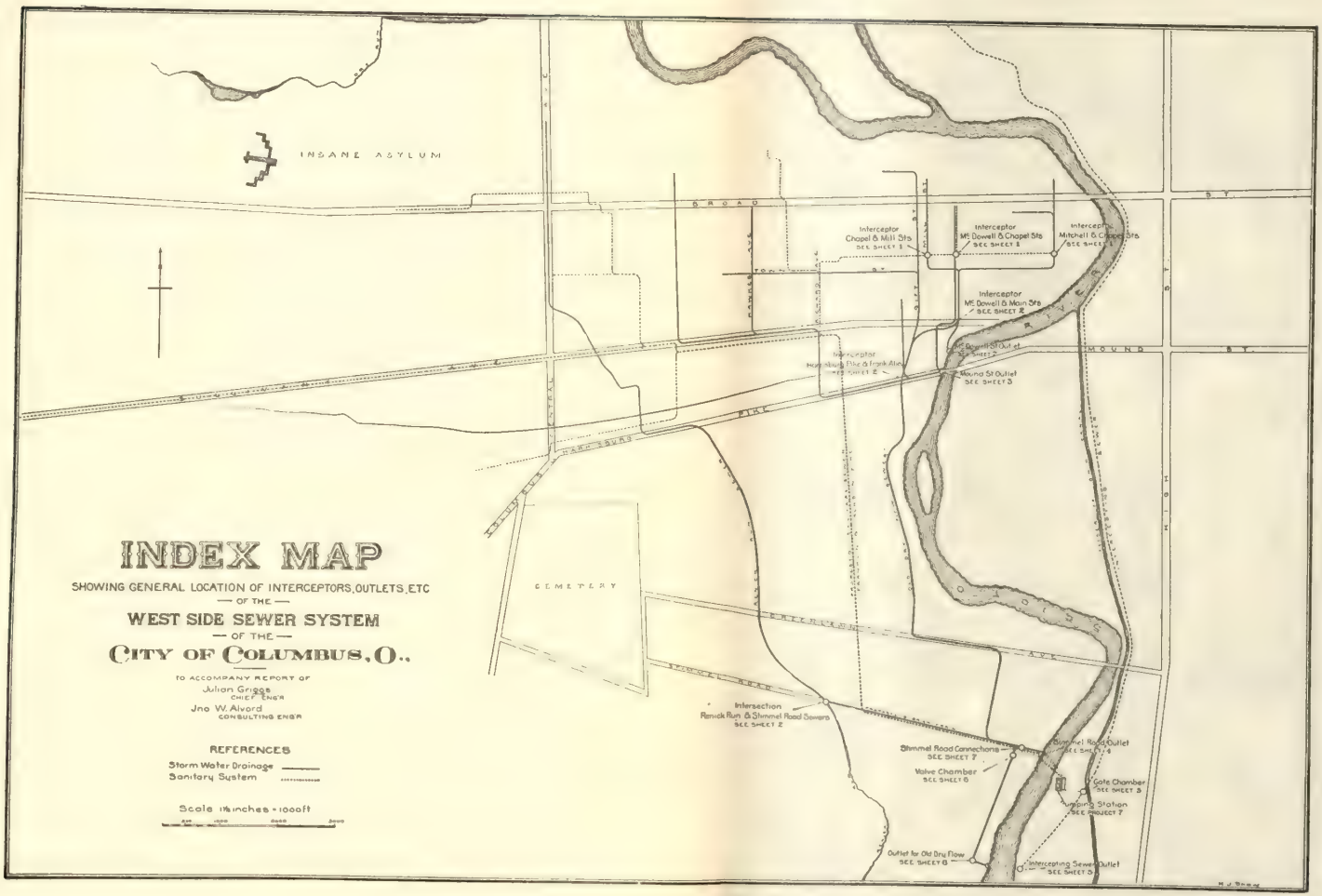
Maximum Capacity of 40000000 Gals Daily

TO ACCOMPANY REPORT OF

Julian Kr[illegible]
CHIEF ENGR

Jno W Alvord
CONSULTING ENGR


7
PLAN & ELEVATION
OF THE
PUMPING STATION
AND
SCREEN CHAMBER
FOR THE
STORM WATER DRAINAGE & SEWAGE
OF THE
CITY OF COLUMBUS, O.
Scale 8 Ft = 1 Inch
TO ACCOMPANY REPORT OF
Julian Griggs
CHIEF ENGR.
Jno W. Alvord
CONSULTING ENGR.
SCALE
SECTIONAL ELEVATION E-F
Looking South
SECTIONAL ELEVATION C-D
Looking North
PLAN
Boiler Room
SIDE ELEVATION
Shewing Section through A-B
END ELEVATION


INSANE ASYLUM
BROAD ST.
MOUND ST.
CEMETERY
SCIOTO RIVER
Interceptor Chapel & Mill Sts SEE SHEET 1
Interceptor Mc Dowell & Chapel Sts SEE SHEET 1
Interceptor Mitchell & Chapel Sts SEE SHEET 1
Interceptor Mc Dowell & Main Sts SEE SHEET 2
Mc Dowell St Out at SEE SHEET 2
Interceptor Hazelburn Place & Frank Alley SEE SHEET 2
Mound St Outlet SEE SHEET 3
Intersection Renick Run & Shimmel Road Sewers SEE SHEET 2
Shimmel Road Connections SEE SHEET 7
Shimmel Road Outlet SEE SHEET 4
Valve Chamber SEE SHEET 6
Gate Chamber SEE SHEET 5
Pumping Station SEE PROJECT 7
Outlet for Old Dry Flow SEE SHEET 8
Intercepting Sewer Outlet SEE SHEET 5

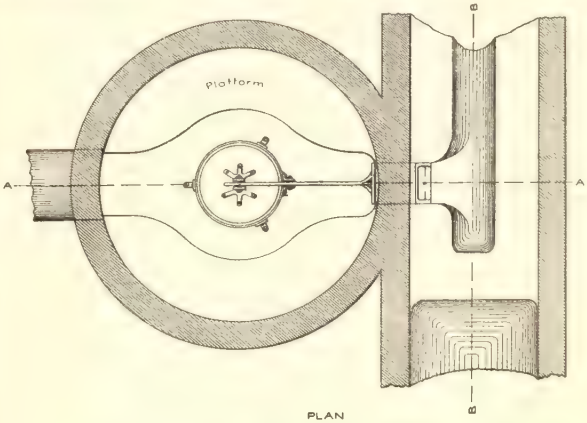
INDEX MAP

SHOWING GENERAL LOCATION OF INTERCEPTORS, OUTLETS, ETC
— OF THE —
WEST SIDE SEWER SYSTEM
— OF THE —
CITY OF COLUMBUS, O.,

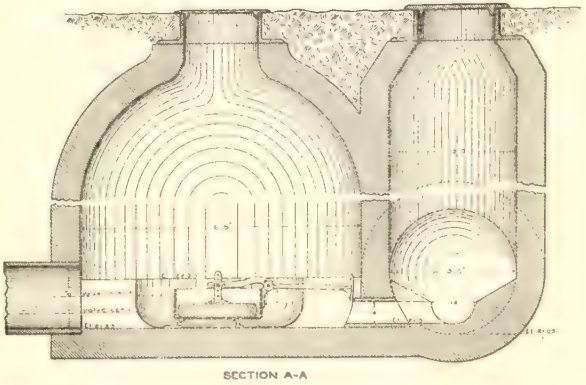
TO ACCOMPANY REPORT OF
Julian Griggs
CHIEF ENG'R
Jno W. Alvord
CONSULTING ENG'R

REFERENCES
Storm Water Drainage ——
Sanitary System ·····

Scale 1⅛ inches = 1000 ft



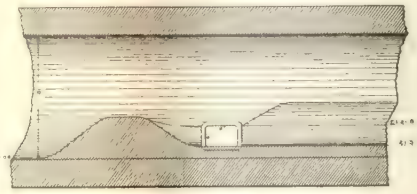
PLAN



SECTION A-A

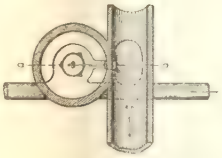
INTERCEPTOR
— AT —
CHAPEL & MITCHELL ST'S

Scale 1 inch per foot

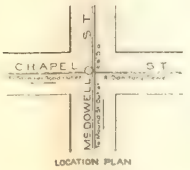


SECTION B-B

SECTION a-a

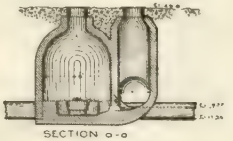


PLAN

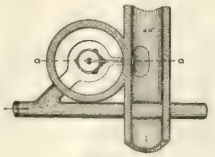


LOCATION PLAN

INTERCEPTOR
— AT —
Mc DOWELL & CHAPEL ST'S



SECTION a-a



PLAN

LOCATION PLAN

INTERCEPTOR
— AT —
CHAPEL & MILL ST'S

PLAN OF

INTERCEPTING CHAMBERS

WITH AUTOMATIC VALVES

— FOR THE —

STORM WATER DRAINAGE & SEWAGE

— OF THE —

CITY OF COLUMBUS, O.,

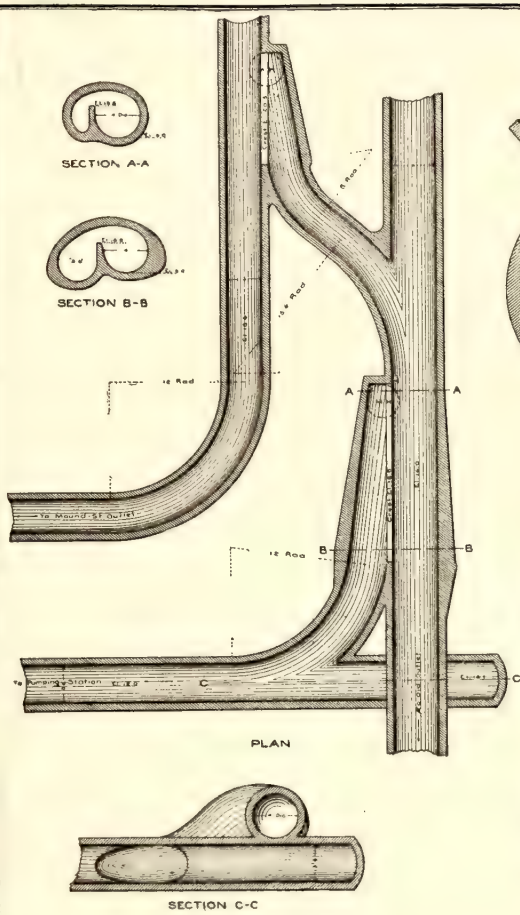
Scale 4 ft per inch

TO ACCOMPANY REPORT OF

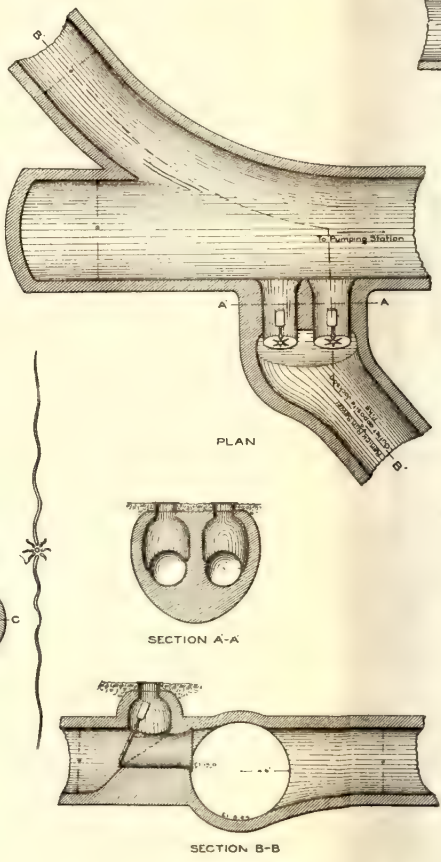
Julian Griggs
CHIEF ENG'R

Jno. W Alvord
CONSULTING ENG'R

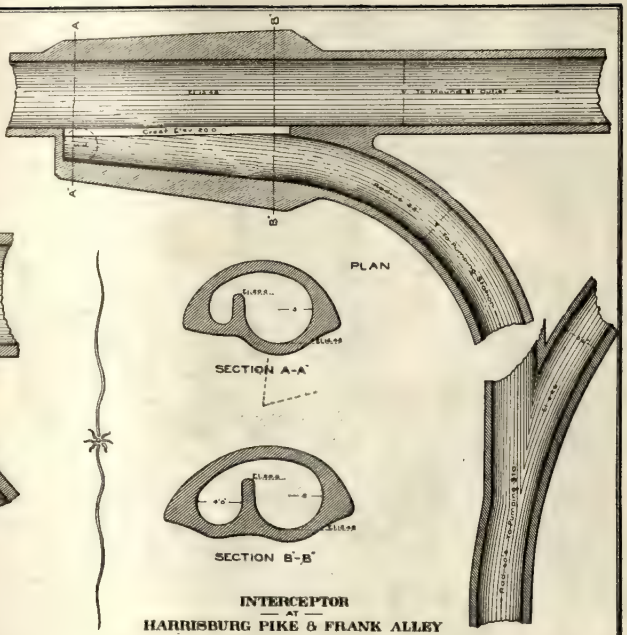
Scale in Feet



INTERCEPTOR
— AT —
Mc DOWELL & MAIN ST'S



INTERSECTION
— OF —
RENICK RUN SEWER WITH STIMMEL ROAD SEWER
Showing Overflow Valves



INTERCEPTOR
— AT —
HARRISBURG PIKE & FRANK ALLEY

PLANS & SECTIONS
— OF —
INTERCEPTING CHAMBERS
— FOR THE —
STORM WATER DRAINAGE
— OF THE —
CITY OF COLUMBUS, O.,

Scale 4 ft per inch

TO ACCOMPANY REPORT OF
Julian Griggs
CHIEF ENGR
Jno. W. Alvord
CONSULTING ENGR

SCALE IN FEET
0 5 10 15

PLAN OF

MOUND ST. OUTLET

— FOR THE —

STORM WATER DRAINAGE

— OF THE —

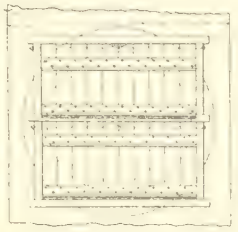
CITY OF COLUMBUS, O.,

Scale 2 ft per inch

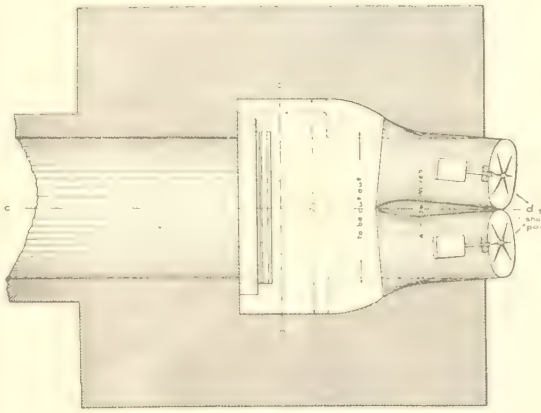
TO ACCOMPANY REPORT OF

Julian Griggs
C.E. & Engr.

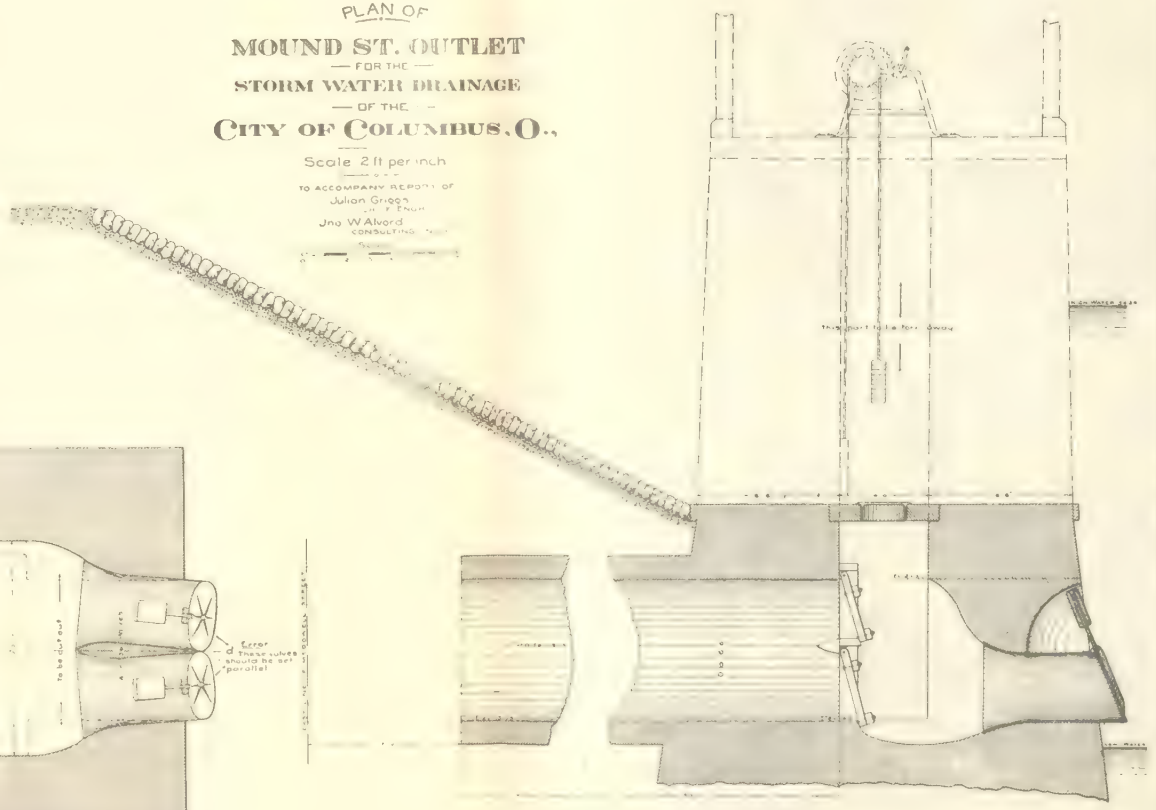
Jno W Alvord
CONSULTING Engr.



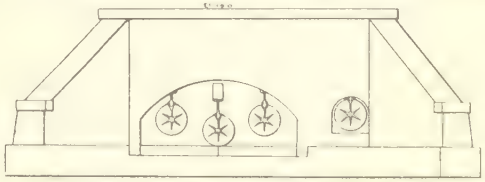
SECTION a-b



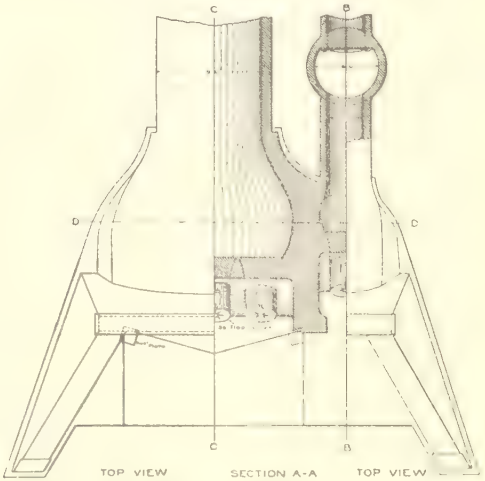
PLAN



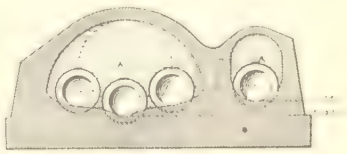
SECTION c-d



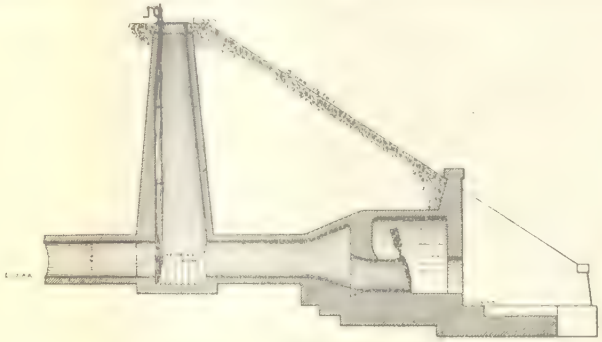
FRONT VIEW



TOP VIEW SECTION A-A TOP VIEW



SECTION D-D



SECTION B-B

SECTION C-C

PLAN OF

STIMMEL ROAD OUTLET

— FOR THE —

WEST SIDE SEWER SYSTEM

— OF THE —

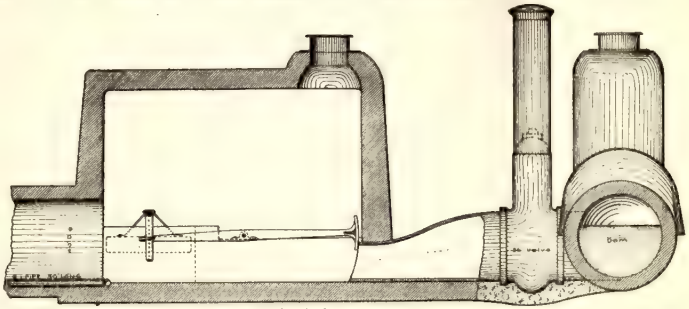
CITY OF COLUMBUS, O.,

Scale 4 ft per inch

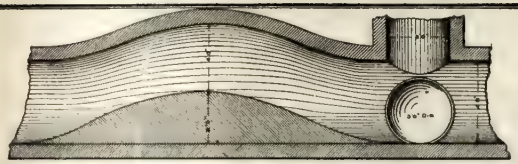
TO ACCOMPANY REPORT OF

Jno W Alvord
CONSULTING ENGR

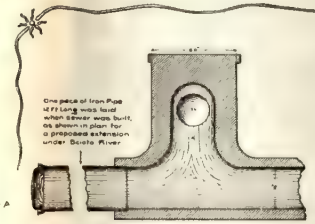
Scale in feet



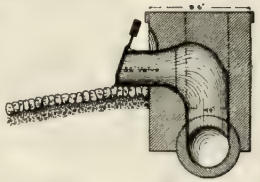
SECTION A-A



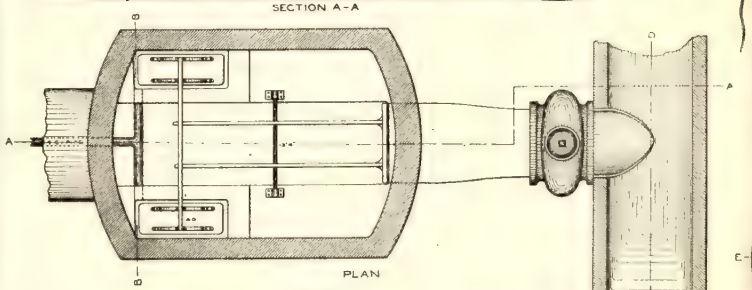
SECTION D-D



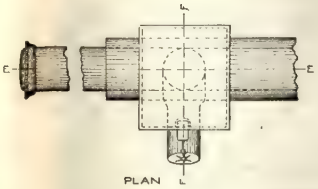
SECTION E-E



SECTION F-F

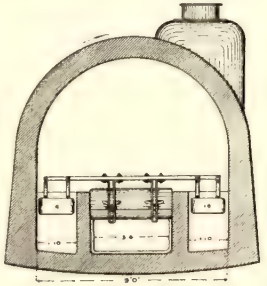


PLAN

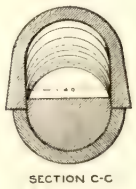


PLAN

OUTLET
OF
INTERCEPTING SEWER
Scale 1 in = 4 ft



SECTION B-B



SECTION C-C

GATE CHAMBER
— FOR —
INTERCEPTING, SEWER NCAA **PUMPING STATION**
Showing Automatic Valve

PLAN OF

GATE CHAMBER & OUTLET

— FOR THE —

STORM WATER DRAINAGE & SEWAGE.,

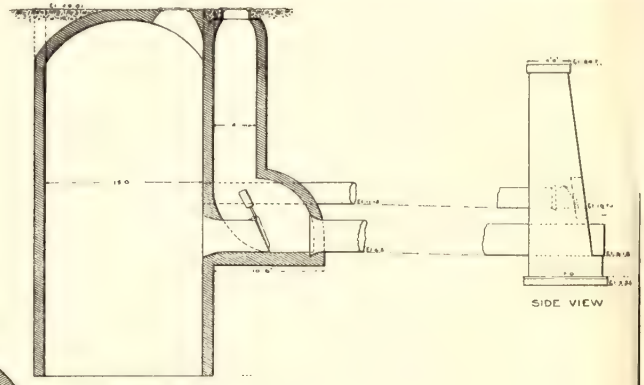
— OF THE —

CITY OF COLUMBUS, O.,

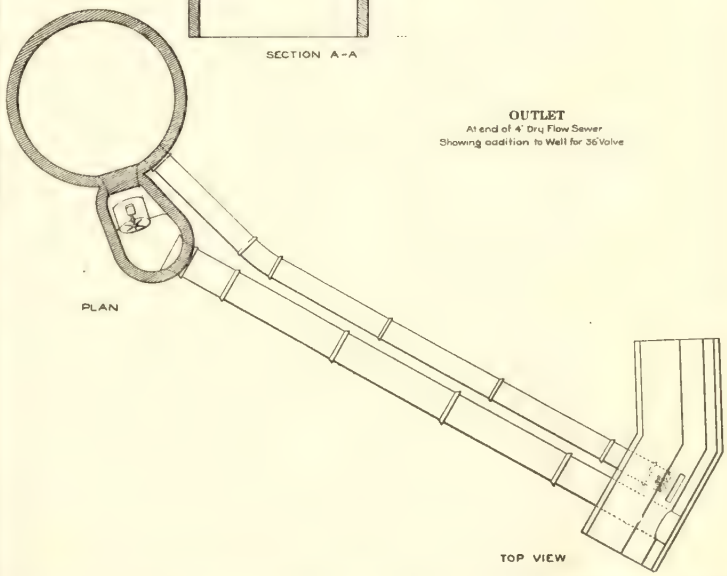
Scale 2 ft per inch

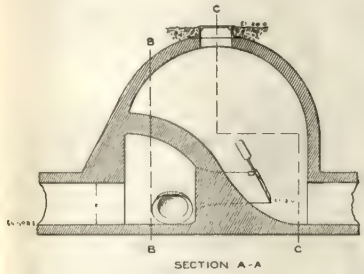
TO ACCOMPANY REPORT OF
Julian Griggs
CHIEF ENGR
Jno W Alvord
CONSULTING ENGR

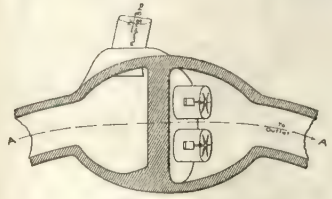
SCALE IN FEET
0 4 8



OUTLET
At end of 4' Dry Flow Sewer
Showing addition to Well for 36 Valve







VALVE CHAMBER
in 4 Dry Flow Sewer near Stimmel Road
Showing 36" Main from Pumping Station

PLAN OF

OUTLET & VALVE CHAMBER

— FOR THE —

STORM WATER DRAINAGE

— OF THE —

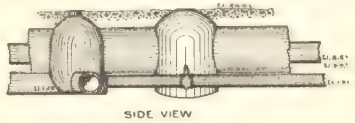
CITY OF COLUMBUS, O.,

Scale 4 ft per inch

TO ACCOMPANY REPORT OF
Julian Griggs
CHIEF ENG'R
Jno W Alvord
CONSULTING ENG'R

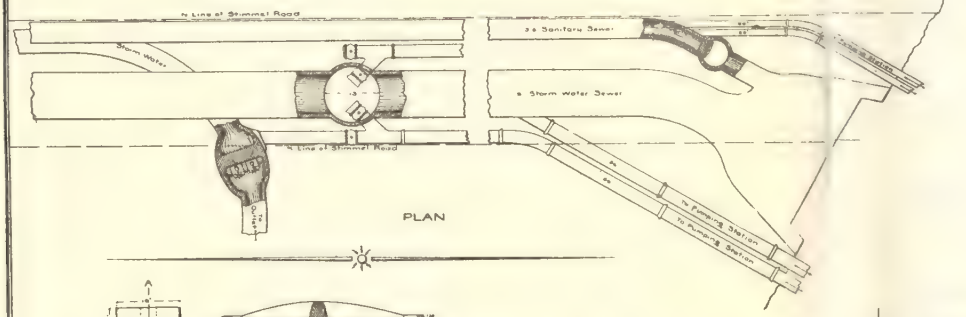
SCALE IN FEET
0 5 10 15

H J Shan



SIDE VIEW

LOCATION PLAN
OF
CONNECTIONS AT STIMMEL ROAD
Showing general location of Mains & Outlet
Scale 10 ft per inch



PLAN

PLANS & DETAILS

STIMMEL ROAD CONNECTIONS, 36" FLAP VALVE & Mc. DOWELL ST. OUTLET

— FOR THE —

STORM WATER DRAINAGE & SEWAGE

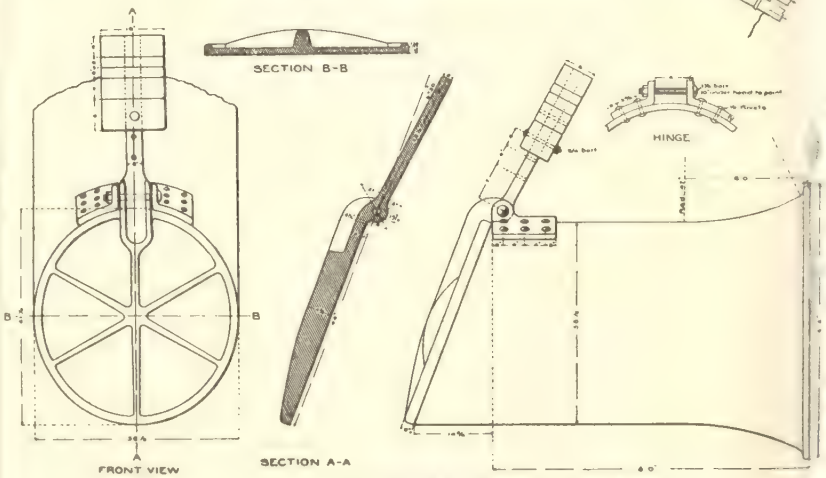
— OF THE —

CITY OF COLUMBUS, O.,

Scale 4 & 10 ft per inch

TO ACCOMPANY REPORT OF
Julian Griggs
CHIEF ENGR
Jno. W. Alvord
CONSULTING ENGR

SECTION B-B

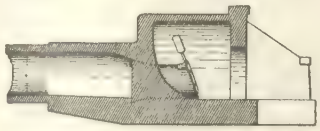


FRONT VIEW

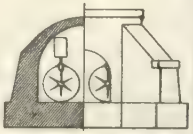
SECTION A-A

SIDE VIEW

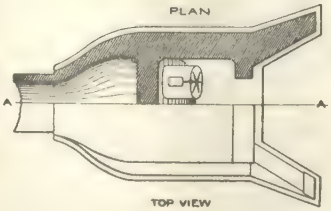
36" CAST IRON FLAP VALVE
Scale 8 in per inch



SECTION A-A

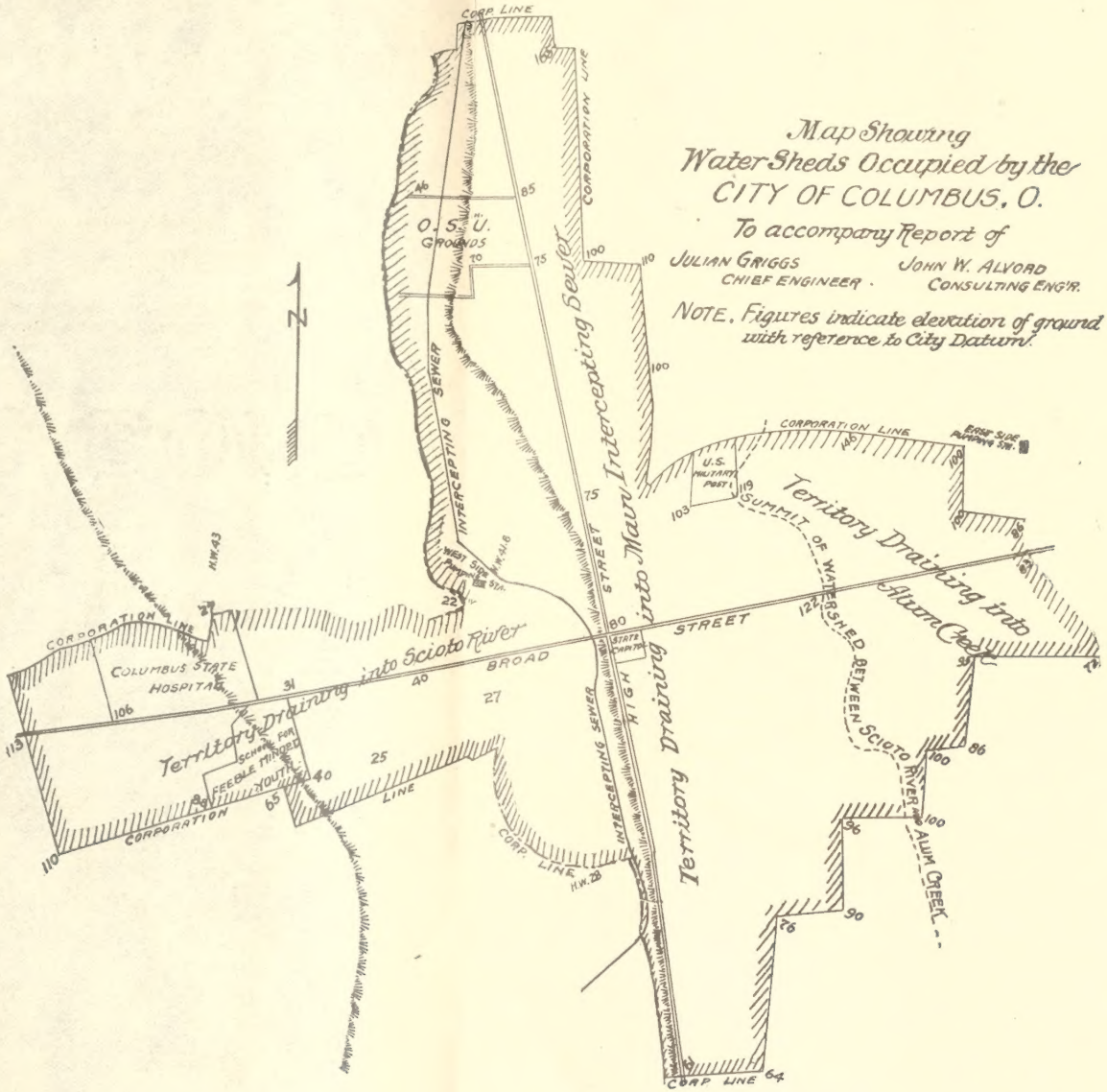


SECTION B-B FRONT VIEW



TOP VIEW

OUTLET
AT
Mc DOWELL STREET
Scale 4 ft per inch


Map Showing
Water Sheds Occupied by the
CITY OF COLUMBUS, O.
To accompany Report of
JULIAN GRIGGS
CHIEF ENGINEER.
JOHN W. ALVORD
CONSULTING ENG'R.
NOTE. Figures indicate elevation of ground with reference to City Datum.
N
CORP LINE
CORPORATION LINE
O. S. U. GROUNDS
INTERCEPTING SEWER
Intercepting Sewer
STREET
Main
into
High
Territory Draining
Territory Draining into Scioto River
Territory Draining into Alum Creek
CORPORATION LINE
U.S. MILITARY POST
SUMMIT OF WATERSHED BETWEEN SCIOTO RIVER AND ALUM CREEK
EAST SIDE PUMPING STA.
WEST SIDE PUMPING STA.
STATE CAPITOL
COLUMBUS STATE HOSPITAL
BROAD
STREET
SCHOOL FOR FEEBLE MINDED YOUTH
CORPORATION LINE
CORP. LINE
INTERCEPTING SEWER
CORP LINE
ALUM CREEK
H.W. 43
H.W. 31.6
H.W. 28

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